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AN INVESTIGATION INTO DEMOGRAPHIC AND MACROSOCIAL CAUSES OF SIX GREENHOUSE GASES

A DISSERTATION APPROVED FOR THE DEPARTMENT OF SOCIOLOGY

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Dedicated to Ryan, without whom none of this is possible, and all of my children.

Thank you, Mom.

I miss you, Dad.

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Table of Contents

List of Tables

List of Figures

Abstract

The single largest ecological crisis facing the world in the coming century is the problem of climate change and its impacts. The state of the world today is the direct result of the history of unequal exchange between wealthy and poor nations, with the footprints of colonization left behind in patterns of unequal trade relationships between high income and low income countries. The crisis of climate change requires a shift in thinking about the social world and the natural world as separate spheres and instead, we must view society as embedded within the natural environment, and acknowledge society's impact on the environment. While climate change impacts must be understood within the context of environmental and climate justice, where social justice intersects with differential access to safe environments. So too must the social structural factors which drive greenhouse gas emissions and their theoretical underpinnings must be analyzed to investigate their relative predictive power to predict greenhouse gas emissions. This research expands upon the body of literature regarding the structural anthropogenic factors which drive greenhouse gas emissions, and improves our understanding of these relationships by analyzing all of the major greenhouse gases including the understudied halogenated species through the lenses of four distinct but related bodies of social theory regarding environmental outcomes including structural human ecology, ecologically unequal exchange, world-system, and world polity theory. I find that structural human ecology factors, when accounting for position within the world-system, serves to predict greenhouse gas emissions, and that civil society predicts an inverse relationship. I close with practical implications based on these findings, including divestment strategy and cap and trade policy.

Chapter 1: Introduction

As we progress through the first quarter of this century, the global social problems of the 21st century are not yet fully known. What is known, with a growing degree of certainty, is that many of these social problems will be rooted, attenuated, or exacerbated by the growing ecological pressures faced as the result of the international drive to economic progress. Climate change represents perhaps the single greatest ecological threat to contemporary society, and macrostructural factors including demography and economy drive greenhouse gas emissions responsible for climate change. Sociology, and the body of environmental sociological theory, seeks to understand the social factors which impact the environment. Economic modernization taking shape through history and persisting through tomorrow has much of its origin story at the start of modern times. Patterns of uneven trade relationships and the division of labor in colonization, the dramatic structural and social change wrought through industrial revolution in Western Nations and their satellites all serve to depict this march of progress at the expense of the natural world. Contemporary examples of this march also come from nations scattered across the globe where fast modernizers' economies develop swiftly through openness to trade with, and extensive demand created by, consumption in the most developed nations. This seemingly inevitable path has all taken place with little or no accounting for the environmental costs of this development at any stage, regardless of localized ecological crises experienced or ecosystems stressed almost to the point of collapse.

The increasing pressure on the climate in the wake of the drive toward modernization hearkens to the rise of self-interest, or selfishness along with societal development promoting individualism marked by disconnection and estrangement from the collective (Burns and Caniglia 2016, Durkheim 1893/1964). Nations across the world all seek to modernize, or improve their economic station or maintain their dominance in the world economy. The emphasis on economics as the salve which cures all ills comes at great cost to the natural environment. Hardin's tragedy of the commons (1968, 1993) points to actors behaving in selfish ways to maximize individual returns, in his illustration, in grazing land to increase the yield of the herd which exhausts and overshoots the ability of the natural environment to survive the selfish impulse of many.

The Dust Bowl era provides a historical example of the impacts that social and economic structural policy and selfish practice can wreak upon the environment, and the rippling consequences for those impacted by a damaged environment. This example is not unique, major ecological catastrophe is often the result or the results are accentuated by human activity, making them social problems rather than natural disasters. Catton (1980) argues that the industrial revolution itself reorganized the structures of society such that we not only fail to account for the outcomes of our actions upon the natural world, but that the consequences for our everyday lives are overlooked almost as if by design, where we were never really meant to see the consequences for our actions at all. Subsistence prior to the industrial revolution relied on renewable sources of energy, with the advent of mechanization and transformation of cultivation through advances in knowledge there came a shift in understanding the potential of the ecosystem from supporting life to endowing life with wealth. "As long as man's activities were based on them [energy sources from organic sources of energy], this was, as church men said, "world without end." That phrase should never have been construed to mean “world without limit,” for supplies can be perpetual without being infinite.” (Catton Jr. 1980).

The drive to improve the human condition through economic progress has both historically, and today come through externalizing or not accounting for the costs to the natural world altogether. Beginning in 1978, with Catton and Dunlap issued the call to environmental sociology, or to abandon the view of humanity as divorced from its natural environment, and instead to place society directly within the context of the environment in which it thrives or dies. The central governing principle of environmental sociology as laid out by its progenitors is to examine the interaction between the environment and society (Catton Jr. and Dunlap 1978). Moving forward with the underlying precept that the environment and society operate in an embedded fashion, I set about to examine how we may reorder societal processes, in particular those involved with modernization, a key concern for the vast majority of countries and peoples in the world. Investigating the structural forces which affect environmental outcomes is critical in order that we may disrupt the current path of economic development, on which currently fails to fully account for the costs ecosystems and the global biosphere pay for development and drives humanity toward growing climate catastrophe for the world’s most vulnerable populations, and for which the extent is not known, but the estimated magnitude of effects seems to grow each year.

Aims and Objectives

The primary aim of this research effort is to understand the structural mechanisms which affect greenhouse gas emissions in a macro-comparative analysis of understudied greenhouse gas emissions, in particular which body of theory best predicts emissions, especially for those greenhouse gases understudied in the social sciences. Climate change represents the single greatest ecological threat to society in contemporary times, worse still than the sheer magnitude of the impacts of climate change are the disparate impacts which will be borne by the poorest and most desperate among less developed nations who are least responsible for the greenhouse gas emissions causing the impacts (Mearns and Norton 2010). Like the historical shift as a result of the Great Depression and the Dust Bowl, climate change in the 21st century is caused by structural social factors which compel individual decision making, and as such, structural adaptations must be made if climate change is to be mitigated. Individual action, while important, and key to eventual change, cannot operate in isolation to address the causes and consequences of climate change, I argue that a larger scope at the macro structural level is the only real way to change course for a problem which has been created not just by individuals, but by large scale structural social, economic, and governmental practice and policy. If we are to address a global problem effectively, it is necessary, but not sufficient to act local, there must be global shifts to achieve solutions.

One of the barriers I address by nature of conducting this research are the silos in which academicians operate based upon their academic field. Generally, the work of natural and social sciences with regard to the environment and environmental impacts operate independently in separate spheres, in spite of the inherently interconnected reality of humans with the natural environment. Indeed, rather than one operating independently of the other, nature provides services and inputs that allow society to exist, grow, and sometimes decay. Likewise, society operates within the natural sphere, creating and changing landscapes and environmental conditions through the operation and unfolding of history. Despite the critical role that the environment plays in the relative success or failure of a society to survive and thrive, the environmental costs are generally excluded from decision-making until they become monetary costs in the form of lost revenue and cleanup. Historical examples of disregard for the environment wreaking financial costs once the ecosystem has been disrupted abound, in the US alone there are 1,323 National Priorities List Superfund Sites listed with the Environmental Protection Agency many of which dating back to the earliest years since the Comprehensive Environmental Response Compensation, and Liability Act of 1980 was enacted (Environmental Protection Agency 2015) but history as yet continues to repeat itself, with new sites proposed to add to the list annually.

Instead of being factored into policy and economic decision making, ecological inputs for society are generally regarded as a given until a crisis emerges, for example, the costs to the ecosystem from pollution and upending the nitrogen cycle with overuse of fertilizers across the states along the Mississippi River and its tributaries are only accounted for once algal blooms downstream become so intense as to create chronic hypoxic dead zones unable to support life such as the one roughly the size of the state of New Jersey in the Gulf of Mexico annually (Ibrahim 2014). Ecosystem and environmental costs are only factored into decision-making once the ecosystem is in distress and costing dollars in lost profits, furthermore quantifying the costs of problems such as hypoxia remain difficult due to the complex of environmental harms that contribute to fish kills and falling populations (Committee on Environment and Natural Resources 2010).

The concept of the web of life illustrates the interconnectedness of all life within ecological communities including critical services provided by ecosystems for human well-being (Rosen et al. 2000). Efforts to quantify the web of life concept demonstrate the complexity and sensitivity of ecology, rather than an ecosystem consisting of linear food chains where species are dependent on each other in a predictable fashion, instead webs exist in a network of direct and indirect interactions (Tylianakis 2008). The web of life concept creates a framework for understanding how disruptions in the ecological web of interaction can and do ripple in both direct and indirect effects. In this research, I use the web of life concept as a heuristic for examining the social structural factors which work as disruptors within the web. Incorporating social structures into the web of life is critical to enhance our understanding of the role that humanity plays as part of this web. Each of the bodies of theory I investigate attempt to connect the social structures of the human world with the natural outcomes of the ecological realm, in this research, through greenhouse gas emissions responsible for climate change.

The Context

Examples for the economic externalization of environmental costs are many, from specific case studies of particular ecosystems, species, or local environments (Bell and York 2010; Frey 2003; Mckinney et al. 2015; Wishart 2012). In addition to these specific treatments for understanding the impacts of economic development on the environment, there is much research on more global and widespread ecological damage (Adeola 2001; Andreoni and Levinson 2001; Bell and York 2010; Bernauer and Kuhn 2010; Dietz, Rosa, and York 2012; Dooley and Fryxell 1999; Ehrhardt-Martinezet al. 2002; Foster 2012; Givens and Jorgenson 2011; Jorgenson et al. 2009; Jorgenson and

Clark 2011, 2012; Jorgenson 2006, 2010, 2012; Khator 2000; Lamb et al. 2014; Macgregor 2014; McKinney 2014; Moore 2011; Nakicenovic and Swart 2000; Pellow and Nyseth Brehm 2013; Rice 2009; Roberts and Parks 2009; Roy Chowdhury and Moran 2012; Rudelet al. 2011; Schlosberg 2013; Shandra et al. 2004, 2009; Vanhaute 2011; Weigert 2008; York et al. 2005). Climate change and its effects, and in particular the structural forces which encourage the emissions of greenhouse gas emissions, represent the most prototypical example of a truly global environmental concern to be faced by humanity in the coming years. According to research on the potential effects of climate change, the world's citizens face one of the gravest threats to the social and natural world in the coming centuries. Several specific categories of outcomes have been identified by the Intergovernmental Panel on Climate Change and that"… anthropogenic warming has had a discernable influence on many physical and biological systems." (2007). Some of these consequences the Panel has identified with a high degree of confidence include changes in snow, ice, permafrost and frozen ground, disruptions to hydrological systems, impacts on terrestrial biological systems, longer thermal growing seasons, and rising water temperatures and the related changes in ice cover, salinity, oxygen, and circulation (Intergovernmental Panel on Climate Change 2007).

Though the physical and biological sciences have much to offer for understanding the environment, the field of sociology, and in particular cross national comparative sociological research, provides the multifaceted framework that the complexity of the human effects on the natural world demands in order to give proper attention to the contextual and relative effects that social structures create in terms of environmental outcomes. Drawing upon a long sociological tradition in which the sociologist operates looking not for a universal law, but for the complex and nuanced theory that relates to a specific context, I employ multiple theoretical perspectives into my investigation on the structures which drive greenhouse gas emissions.

Historical and comparative approaches to understanding the social world, particularly from a macro level are an essential piece of the quest to understand the social world as it is, *talis qualis*, and the consequences of "business as usual" structural modernization processes. Although this picture of the world, and answers sought for complex global phenomena cannot be seen as final and complete without the work of qualitative researchers who unveil the inherent differences among peoples and nations, I argue that focusing on the nation state as the unit of analysis provides the large scale picture necessary for explaining the absolutely large scale problem of climate change and I build upon the work of many in the field of environmental sociology in this vein (Givens and Jorgenson 2011; Gould, Pellow, and Schnaiberg 2004; Jorgenson et al. 2014; Pellow and Nyseth Brehm 2013). Furthermore, when answering questions regarding large scale environmental problems, individual case studies provide needed context, but macro level comparative methods provide a wider lens appropriate to the wide problem of climate change and provide the critical structural level information necessary to adapt society in order to achieve climate justice in the 21st century.

Research Question

My research question asks, which theoretical perspective best predicts the societal mechanisms which drive greenhouse gas emissions? The drivers for climate change, whether deforestation, consumption etc. are part of the broader functioning of society especially in the pursuit of modernization and economic development. Uncovering which theory best predicts greenhouse gas emissions is critical to implementing policy which may reduce emissions, and therefore the impacts on the world's most vulnerable populations. This research is situated in the larger conversation of sociological research connecting individual experience to larger social forces in the vein of Mills' sociological imagination (1959). Unveiling the theories which best predict environmental outcomes, specifically greenhouse gas emissions, can and should inform public policy and personal practice to face the impending shifts as a result of climate change, and to reduce emissions to prevent further harms.

In the present, environmental regulations exist scattershot, where some countries wholeheartedly adopt policy to incorporate sustainability in decision-making processes that drive political and economic policy, while others, particularly those contributing the most greenhouse gases relative to their peers to the environmental crisis, do little more than provide lip service to the concerns of the environment, and at worst, insist that economic development itself will create solutions to the problems generated by economic development (Hovi, Sprinz, and Bang 2012). In regards to public opinion on climate change, and its importance, much work in the social sciences has focused on the psychological, rather than social aspects of beliefs on climate change (Shwom et al. 2015). Engaging sociological theory to predict greenhouse gas emissions can serve as a means to engage public opinion where existing calls to climate change awareness and acceptance have failed.

The interlocked nature of both society and the natural world calls for an interconnected and multifocal approach to understanding this basic question of the structure of society necessary to ensure the safety and preservation of the complex and interconnected physical world. This work seeks to unveil the varying processes that drive global environmental harms in the process of development for emerging nations, and the maintenance of economic achievement for the most developed nations. Rather than focusing on a single theoretical perspective, or outcome measure, I apply a comparative sociological lens to the problem of greenhouse gas emission drivers and cross national species loss. I employ multiple theoretical explanations for these environmental outcomes, to evaluate their respective predictive power for each of the major greenhouse gases known to contribute to climate change.

My work will add to our understanding of the causes of climate change by investigating which theory of the structural pathways which drive emissions for the most studied emissions (carbon dioxide and methane, respectively,) operate the same, or differently looking cross nationally and comparatively and including the rest of the greenhouse gases, especially those that result solely from anthropogenic activity. If climate justice is to be achieved in the 21st century, structural change must be made and disruptions made to business as usual modernization, trade, and democracy.

Chapter 2: Literature Review

Theoretical Perspectives on Structural Drivers of Climate Change

The literature regarding the human drivers of climate change crosses several disciplines including physical and biological sciences, economics, geography, history, and sociology. As a multidisciplinary study, the theoretical framework which influences individual researchers may be wildly different, even while investigating the problem using similar, or even the same variables which in turn can lead to differing interpretations over similar results. In this research, I will investigate three major bodies of theory regarding the anthropogenic drivers of environmental impacts including Structural Human Ecology, Ecologically Unequal Exchange, World-System Theory, and World Polity Theory.

Over the course of this literature review, I lay out the four major schools of thought within sociology regarding the structural causes for greenhouse gas emissions. The vast majority of this research, which becomes more clear as I progress through each of these bodies of theory, focuses on carbon dioxide and methane emissions, and other ecological impact variables such as deforestation, species loss, and ecological footprint (a theoretical and empirical model which estimates per capita footprint or ecological resources necessary to maintain the current levels of consumption per capita) (Rees and Wackernagel 2013). This dearth of scholarship regarding nitrous oxide gas emissions and the halogenated species of greenhouse gases from a social structural and comparative perspective provides the window into which I propose the greatest potential for climate change disruption may take place in the coming years.

Structural Human Ecology Perspectives

Structural Human Ecology perspectives, despite controversial beginnings pinpointing population size as the primary driver for environmental harms (Ehrlich and Holdren 1971; Holdren and Ehrlich 1974), have been shown repeatedly to serve as strong predictors for environmental impacts deforestation, carbon dioxide and methane emissions, ambient air pollution, and natural resource and fossil fuel consumption (Burns, Davis, and Kick 1997; Ehrhardt-Martinez 1998; Jorgenson and Clark 2010;

Rosa and Dietz 2012; Rosa et al. 2004; York, Rosa, and Dietz 2003; York and Rosa 2003).

A variety of methods employed by previous cross national researchers find population persists as a positive predictor for greenhouse gas emissions. Time series analyses of this impact of population on the environment find that population changes have a greater than proportional impact on carbon dioxide (Jorgenson and Clark 2010). Population theories of environmental impact propose that environmental harms are a function of the relationship between population, affluence and technology. The IPAT equation (I)=(P)(A)(T) predicts environmental impacts (I) as a multiplicative function of population (P), affluence (A), and technology (T) (Ehrlich and Holdren 1971; Holdren and Ehrlich 1974). The model has since been refined and specified, first as a reformulated equation known as STIRPAT, where stochastic (ST) environmental impacts (I) are predicted by regression (R) on population (P), affluence (A), and technology (T) as an error term (Ehrhardt-Martinez 1998; Rosa et al. 2004; York et al. 2003a, 2003b). In recent years, the Kaya Identity has been adopted by the Intergovernmental Panel on Climate Change for projections of greenhouse gas emissions. The Kaya Identity maintains population as a primary factor in predicting emissions scenarios with a near match equation to the IPAT formulations, where Total Emissions = (population)(GDP/population)(energy/GDP)(emissions/energy) (Nakicenovic and Swart 2000). Both the Kaya and STIRPAT formulations form the baseline model for which most theoretical perspectives build upon for investigating the anthropogenic drivers of greenhouse gas emissions, population and affluence are necessary control variables by nature of the predictive power they hold in investigating the variance in emissions cross-nationally, and their utility as a foundation upon which to build analyses of competing theories such as ecologically unequal exchange and world polity theories.

Structural human ecological theories which employ population analyses, in particular, have revealed that population in total does not operate in a uniform fashion in its effect on greenhouse gas emissions. Instead, the character and quality of a population makes a difference in the relationship between population and emissions. Particularly of interest are recent findings regarding the role of urbanization in driving greenhouse gas emissions. Evidence from previous research indicates that urbanization increases territorial emissions of carbon dioxide. The theorized path through which urbanization increases emissions comes as access to electricity grows alongside rates of urbanization. It stands to reason that increased access to electricity will increase electricity consumption and therefore increase greenhouse gas emissions, in particular carbon dioxide in nations where power derives from coal fired plants, and sulphur hexafluoride which is emitted as a result of electricity transmission. (Jorgenson 2012; Lamb et al. 2014; Liddle and Lung 2010; Myhre et al. 2013). The inclusion of urbanization also serves to better specify STIRPAT theoretical construct, where the final T for technology is measured indirectly through urbanization (McKinney, Kick, and Fulkerson 2010; York et al. 2003).

In addition to the effects of urbanization on greenhouse gas emissions, another demographic characteristic, the age dependency ratio, has shown to have an increased impact on greenhouse gas emissions (York et al. 2003; York 2008). Non-dependent population, or the percentage of the population considered working age, 15-64 years old, often consume resources and generate greater waste emissions relative to those under 14 and over 65. This effect has been observed both with greenhouse gas emissions, specifically carbon dioxide, and with deforestation and ecological footprint analyses (Shandra et al. 2011; York et al. 2003).

Neoliberal explanations for greenhouse gas emissions, often referred to the sociological literature as the modernization approaches to greenhouse gas emissions view population as a baseline factor, but equally important for consideration is affluence, and in particular, the nonlinear fashion in which affluence in particular has been shown to exhibit with respect to a variety of national level dependent variables including air pollution, global ecological footprint, threatened species, and deforestation (Andreoni and Levinson 2001; Ehrhardt-Martinez et al. 2002; McKinney et al. 2010; Roberts, Grimes, and Manale 2003). The so-called environmental Kuznets curve is an attractive heuristic for modernization proponents as the theorized relationship between affluence and environmental harms is hypothesized to follow an inverse U shaped path, where initial increases in average incomes increase environmental harms, but at a certain level of development there comes a point of diminishing return whereby additional gains in affluence result in less environmental harms (Grossman and Krueger 1995; Kaika and Zervas 2013; Kuznets 1955; Torras and Boyce 1998; York et al. 2005; York et al. 2003a).

Ecologically Unequal Exchange

Ecologically Unequal Exchange provides an avenue where researchers may unveil the role of economic dependence, or economic dominance affects environmental impacts. This body of theory is rooted firmly in the tradition of investigating the relationships between nations, in particular the extractive and inherently unequal character and history of these relationships most often characterized by an inherently unequal trade relationship of extraction of natural resources from less developed countries, or the export of waste or "dirty" pollution intensive activity to less developed countries in exchange for increased economic activity at market values (Hornborg 1998). This notion of unequal exchange arose as a critique of the theory of comparative advantage (Rice 2009; Wallerstein 2004).

The ecologically unequal exchange literature stems from earlier theorizations of the metabolic rift in society, where raw materials are extracted in one place and moved to another. This spatial inequality upends the ecology of both sites, such as in the case of Appalachian mountaintop removal in the US (Austin and Clark 2012) and in the increasing distance between environmental outcomes and the social processes which create them (Foster 2012). Greenhouse gas emissions, specifically the carbon cycle, provides a prototypical example of this rift, where the efforts of modernization promote increased urbanization, and increasing distances between the sites of extraction and consumption (York 2008).

Focusing on trade and trade dependence between less affluent nations with the most affluent nations, researchers have found that more impoverished nations are likely to suffer greater environmental impacts as a result of these unequal relationships where extractive industry or particularly "dirty" economic activity takes place in less affluent nations and extracted raw materials, or finished goods are then exported to high income countries (Jorgenson 2012; Rice 2009). The results of this unequal relationship have been demonstrated to lead to increased environmental harms in the form of per capita carbon dioxide gas emissions, deforestation, ecological footprint (Jorgenson et al. 2009; Jorgenson and Clark 2011; Jorgenson 2010, 2011, 2012; Shandra et al. 2009).

The drive toward ever increasing economic prosperity among and within wealthy countries creates a situation in which the pursuit of consumption and thereby production overrides concerns not directly related to increasing revenues. This treadmill of production creates a social and economic environment where the drive to profit encourages natural resource extraction, environmentally unsustainable practice, and pushes productivity at all costs (Gould et al. 2004). The treadmill of production forms part of the background from which the ecologically unequal exchange literature derives. From the perspective of the capital holders, should regulatory bodies impose regulations aimed and promoting sustainability or secure the safety of the environment then the calculation is made that these regulations may reduce production, a violation of the treadmill's aim. In response to increased regulations, the easy answer is for these industries is to move across borders where those regulations do not exist, or perhaps more troublingly, may exist but are not enforced (Frey 2003; Gould et al. 2004; Pellow and Nyseth Brehm 2013; Rudel et al. 2011).

Ecologically unequal exchange, drawing upon the treadmill of production literature, understands that consumption is a primary driving force for environmental harm. Ecologically unequal exchange enhances the previous notions of the treadmill concept where the environmental costs of consumption are not borne in the nations where the consumption takes place, or the 'resource consumption/environmental degradation paradox.' This paradox reflects the relationship between the resources consumed in a given country and whether the environmental degradation is wrought within that nation, or by another less affluent nations (Hornborg 2001, Jorgenson 2003, Jorgenson et al. 2009, Rice, 2008). In other words, the consumption of natural resources, which is insatiable in the most dominant and developed nations comes not at the cost of the dominant nation's nature and environment, but from less powerful countries. From this ecologically unequal exchange perspective, the environmental consequences of unequal exchange between wealthy and less developed nations are great.

Ecologically unequal exchange analyses employ measures to capture the vertical flow of trade from less affluent to high income countries, keeping in the tradition of metabolic rift and its spatial inequalities. Quantifying the character of this trade has developed over the years, beginning with measures of foreign capital penetration as the percentage of gross domestic product resulting from foreign direct investment (Chase-dunn and Grimes 1995; Grimes and Kentor 2003). As the scholarship developed, weighted export flows became the commonly utilized approach to approximating the relationship between wealthy and less affluent nations and was found to predict deforestation, carbon dioxide emissions, biodiversity loss, ecological footprint (Jorgenson et al. 2009; Jorgenson and Clark 2011; Jorgenson 2010; Shandra et al. 2009). Weighted export flows as a measure take into account the form of primary sector exports between sending and receiving nations, and the level of affluence in receiving countries (Jorgenson et al. 2009). Although this measure proved useful, the most recent analyses now turn to a more readily interpreted variable for modeling ecologically unequal exchange, a variable from the World Bank which calculates the percentage of a country's exports of manufactured goods to high income countries,

countries classified as the most affluent according to the World Bank by gross domestic product per capita (World Bank 2015). This new operationalization for uneven trade has proved methodologically sound and has been demonstrated to predict per capita carbon dioxide emissions and is highly correlated to weighted export flows (Jorgenson 2011, 2012).

Concerning greenhouse gas emissions, this ecologically unequal exchange theorization is particularly salient, the appetite for energy, and consumer demands in wealthy countries may increase the production of those most damaging halogenated species of greenhouse gases, ecologically unequal exchange theories, provide an avenue to investigate the understudied but human activity dependent greenhouse gas emissions.

World-System Theory

Contemporary ecologically unequal exchange shares its tenets with a body of world-systems research into ecology and environmental harm. Theorizations of the world-system provides a useful heuristic for envisioning relationships between wealthy and less affluent nations not just in a cross sectional sense, but taking into account the scope of history in creating and sustaining inequality between nations. At its root, world-systems perspective recognizes that the legacy of colonialism, and the footprints today of neocolonialism shaped the modern world in very real ways from the political boundaries recognized as states, to the dependent character of many relationships between formerly colonized lands and peoples on their former colonizers (Wallerstein 2004). As an analytical framework, world-system position has been modeled to capture the consequences for a nation's position with the world-system as it relates to a variety of outcome measures including carbon dioxide emissions, per capita carbon dioxide emissions, individual environmental concern, threats to bird and mammal species, ecological footprint, material extraction including biomass, minerals, and fossil fuels, ground level air pollution (Ergas and York 2012; Givens and Jorgenson 2011; McKinney et al. 2010; Mckinney 2012; McKinney 2014; York and Rosa 2012; York et al. 2011).

Quantifying a nation's position within the world-system for the purposes of analysis relied heavily on early formulations rooted in the philosophical and analytical framework set forth by the theory's founder, Immanuel Wallerstein, the most well respected network analysis of world-system position based on block positions within a social and economic network was formulated by Snyder and Kick (1979) providing a trichotomous measure of world-system position. A new formulation of blockmodel positions using more recent data was released in 2011, and has been used to demonstrate the effects of world-system position on environmental outcomes such as carbon dioxide emissions and species loss (Ergas and York 2012; Kick et al. 2011; McKinney et al. 2010). This measure is a social network analysis for the years 1995-1999 and includes transnational economic, political, cultural, and military exchanges for 160 among four relational dimensions including trading partners, memberships in international non-governmental organizations, embassy sponsorship, and arms transfers which resulted in 10 distinct blocks within the modern world-system (Kick et al. 2011; York and Ergas 2011). The world-system position measure created by Kick et al. employed the CONCOR program in UCINET to identify block groups based on their structural equivalence, or the extent to which nations mirrored identical relationships to other nations (2011). World-System block positions are available in the Appendix in

Table 20. The CONCOR program initially divides the sample into two groups of structurally similar nations, and then proceeds to continue dividing nations into additional pairs of groups until a single nation occupies a block group or all groups have similar network relations. Utilizing the degree of centrality as a criterion test for the validity of the block groups, Kick et al. (2011) identified outliers. Some of these outliers at face seem like strange bedfellows within a particular block, for example Canada in Block 3 among Asian nations in the "Asian Block," although this grouping on its face seems counterintuitive geographically, what matters in determining position is not physical position, but the structure of network linkages for a particular nation. In this case, Canada's relations regarding political, economic, cultural, and military exchanges are far more similar in structure to their peers amid the "Asian Block" than the Western European Block.

Although these block positions number greater than the original theoretical formulation set forth by Wallerstein, and the contributions of scholars who recognize a semi-core in addition to the core, semi-periphery, periphery conception of the world-system, this measure based on network linkages can still be interpreted in the more orthodox view of world system position through the recognition of these block model positions as representing a spectrum world-system positions of relative coreness and peripherality, or a "continuous metric of democracy and dependency instead of more discrete types" (Kick et al. 2011:324). The utility and interpretability of the new block model measure far outweighs any departure from orthodoxy in world-system position definition. This new measure has been employed by researchers investigating the role of women in carbon dioxide emissions, and the position of women within the world-system (Ergas and York 2012; York and Ergas 2011). This block model approach to measuring the World-System is not without cost. Moving beyond the orginial world-system framework of core/semiperiphery/periphery, or the core/semi-core/semi-periphery/periphery framework set forth by Wallerstein (1974) and other world-system position analyses (Bollen 1983, Burns et al. 2003) represents a significant departure from the theorized network of relations conceived of as the world-system. By engaging ten block positions instead of 3 or 4, the danger exists of diluting the positional nature of world-system classification into a measure continuous in nature as opposed to a truly discrete position. Keeping this potential drawback in mind, I choose to utilize the Kick et al. (2011) block position model due to the network analysis from which it is derived being most applicable to understanding the commitments and relationships internationally which drive greenhouse gas emissions. Prior research utilizing this block model framework has been demonstrated to predict carbon dioxide emissions and species loss (Ergas and York 2012; McKinney et al. 2010).

World Polity Theory

The third major school of thought I engage in the comparative study of greenhouse gas emissions is world polity theory. Civil society, as it interacts within a country through open and transparent governance and international non-governmental organizations, has been demonstrated to mediate the impacts of environmental harm through the creation and maintenance of world cultural, especially, environmental norms (Hironaka and Schofer 2000; Smith et al. 2005). International non-governmental organizations, in particular those with an explicit environmental focus, work as agents for change within countries to support sustainable practices including those affecting greenhouse gas emissions, deforestation, water pollution, greater land protection, number of threatened mammal species, and boost participation in international environmental treaties (Bernauer and Kuhn 2010; Jorgenson et al. 2011; Jorgenson 2009, 2010; Schofer and Meyer 2005; Shandra et al. 2009; Shandra et al. 2004; Smith et al. 2005).

The world polity perspective's foundations are rooted in a macrophenomenological conception derived from the sociological institutionalism literature (Meyer et al. 1997). The Polity IV index is a composite measure to gauge a nation's level of institutionalized democracy versus institutionalized autocracy each on 11 point scales where coders rate individual nations for their respective levels of democracy and autocracy. Institutionalized democracy is composed of three primary elements including the presence of institutions and procedures for citizens to express preferences for policy and leadership, the existence of institutionalized constrains on the exercise of power by the executive, and the guarantee of civil liberties to all citizens in both daily life and through political participation. Institutionalized autocracy on the other hand, is conceptualized as a set of political characteristics which tend to suppress and restrict political competition. Specifically, more autocratic nations select chief executives through a process within the poetical elite, and once in office, these executives operate with little institutional constraints. Nations are scored for both democracy and autocracy by a panel of coders to increase inter-coder reliability through tests and special attention to internal consistency, and once scored, the combined Polity IV score is attained through subtracting the autocracy score from the democracy score (Marshall 2014). The Polity IV index serves as a snapshot of a nation's relative level of democracy and is well documented as a way to assess the robustness of civil society within a country investigating world polity theory (Bernauer and Kuhn 2010, Shandra et al. 2009, Shandra et al. 2011, York and Rosa 2012, Zhou 2015).

In addition to a nation's level of democracy, the presence of international non-governmental organizations is theorized to provide the mechanisms through which cultural change diffuses. International non-governmental organizations, as measured by the Center for Systemic Peace are classified according to four types of non-governmental organizations including federations of international organizations, universal membership organizations, intercontinental membership organizations, and regionally defined organizations. The organizations recognized by the Center for Systemic Peace come from the International Yearbook from the Union of International Associations (Marshall 2014). The International Yearbook is an often utilized source for quantifying non-governmental organizational presence in comparative research (Givens and Jorgenson 2013, Hironaka and Schofer 2000, Jorgenson et al. 2011, Parks and Roberts 2006, Schofer and Hironaka 2005, Smith and Wiest 2005, Zhou 2015)

Civil society is theorized to operate in terms of broad, institutional effects where institutional structures comprised of a vibrant civil society through discourse, cultural models, organizations etc. diffuse their influence across all levels of the social system, which is theorized to increase amenable policy and law, increased social movements, new corporate standards, values shifts, and eventually a move toward improving environmental outcomes (Schofer and Hironaka 2005). This process unfolds within societies with open, democratic structures. Civil society also plays a vital role in accountability of elected officials and business interests, the broadcast and dissemination of education regarding the environment, and empower grassroots local movements with tools and resources to bring change to their locale. States with more open and transparent democracies are more likely to allow, as opposed to suppress INGOs as well as to be more responsive to civic action (Ehrhardt-Martinez et al. 2002; Jorgenson 2009; McKinney 2014; Zhou 2012).

The interaction between state capacity for International Non-governmental organizations and level of democracy provides an indication of where INGOs are most likely to enjoy participation and acceptance (Smith et al. 2005; Zhou 2012). The world polity approach emphasizes the role of culture in changing the state of environmental affairs. A world polity culture of environmental protection diffuses through a global culture, specifically through the work completed by nations and non-governmental organizations as they work to change the attitudes and behaviors of citizens resistant to change (Pellow and Nyseth Brehm 2013).

Climate Change

Climate change represents one of the gravest threats to the social and natural world in the coming centuries. Heeding the call of the American Sociological Association to investigate the Anthropogenic Drivers of Climate Change (ASA 2010), this work seeks to unveil the varying processes that drive greenhouse gas emissions. Rather than focusing on a single theoretical perspective, or outcome measure, I apply a comparative sociological lens to the problem of greenhouse gas emission drivers. I employ multiple theoretical explanations for greenhouse gas emissions to evaluate their respective predictive power for each of the major greenhouse gases known to contribute to climate change. My work will add to our understanding of the causes of climate change by investigating whether the structural pathways which drive emissions for the most studied greenhouse gases (carbon dioxide and methane emissions, respectively,) operate in the same fashion, or as I suspect, differently looking cross nationally and comparatively.

The growing consensus among the scientific community that there have been climactic changes in recent years, and these changes are the result of dramatically increased anthropogenic emissions of greenhouse gases (Pachauri et al. 2014). Furthermore, the Intergovernmental Panel on Climate Change has concluded that the warming of the climate system is both unequivocal and unprecedented in human history, the atmosphere and ocean have warmed, snow and ice are diminished, and consequently sea levels are rising (Pachauri et al. 2014). The anthropogenic increase in greenhouse gas emissions has led to demonstrable warming of the climate according to the IPCC (Pachauri et al. 2014). This dramatic increase is depicted in Figure 2.

Figure 1. Total annual anthropogenic greenhouse gas emissions

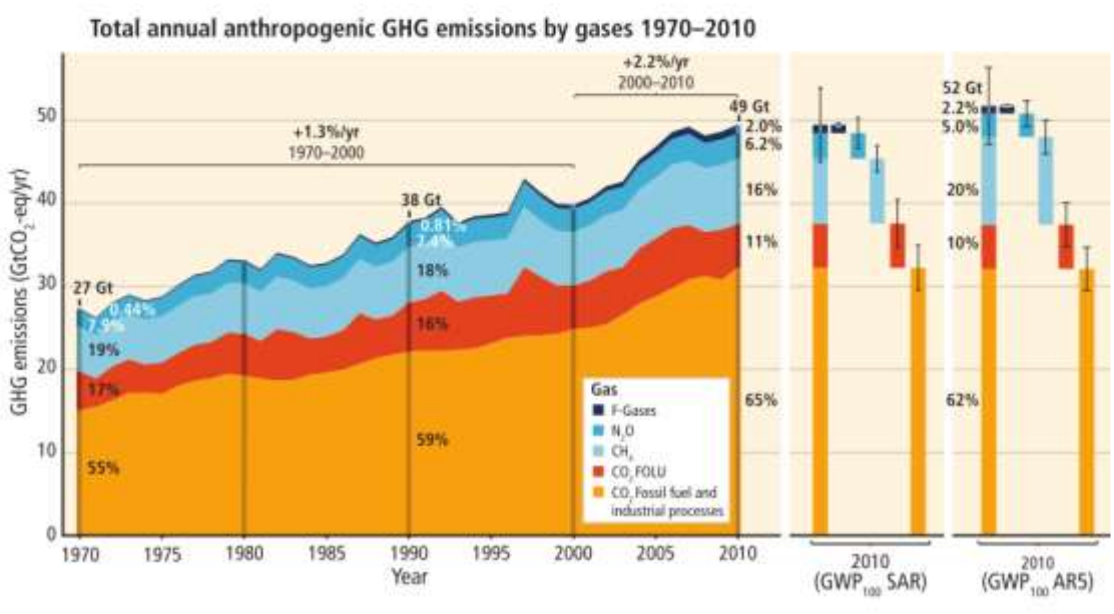

Figure 2. Total annual anthropogenic greenhouse gas emissions (gigatonne of CO2 equivalent per year) for the period 1970-2010 by gases. From Climate Change 2014: Synthesis Report (Pachauri et al. 2014).

The Intergovernmental Panel on Climate Change has published key consensus findings regarding climate change in the 2014 Synthesis Report including:

> Human influence on the climate system is clear, ad recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems. {1}
>
> Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen. {1.1}
>
> Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentration of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropocentric drivers, have been detected throughout the climate system and are *extremely likely* to have been the dominant cause of the observed warming since the mid-20th century. {1.2, 1.3.1}
>
> In recent decades, change in climate have caused impacts on natural and human system on all continents and across the oceans. Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate. {1.3.2}
>
> Changes in many extreme weather and climate events have been observed since about 1950. Some of these changes have been lined to human influences, including a decrease in cold temperature extremes, an increase in warm temperature extremes, and increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions. {1.4}
>
> Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of sever, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks. {2}
>
> Cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary over a wide range depending on both socio-economic development and climate policy. {2.1}
>
> Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise. {2.2}
>
> Climate change will amplify existing risks and create new risks for natural and human systems. Risks are unevenly distribute and are generally greater for disadvantaged people and communities in countries at all levels of development. {2.3}

Many aspects of climate change and associated impacts will continue for centuries, even if anthropogenic emissions of greenhouse gases are stopped. The risks of abrupt or irreversible changes increase as the magnitude of the warming increases. {2.4}

Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Substantial emissions reductions over the next few decades can reduce climate risks in the 21st century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term and contribute to climate-resilient pathways for sustainable development. {3.2, 3.3, 3.4}

Effective decision-making to limit climate change and its effects can be informed by a wide range of analytical approaches for evaluating expected risks and benefits, recognizing the importance of governance, ethical dimensions, equity, value judgements, economic assessments and drives perceptions and responses to risk and uncertainty. {3.1}

Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of sever, widespread and irreversible impacts globally *(high confidence)* Mitigation involves some level of co-benefits and od risks due to adverse side effects, but those risks do not involve the same possibility of sever, widespread and irreversible impacts as risks from climate changes, increasing the benefits from near-term mitigation efforts. {3.2, 3.4}

Adaptation can reduce the risks of climate change impacts, but there are limits to its effectiveness, especially with greater magnitudes and rates of climate change. Taking a longer-term perspective, in the context of sustainable development, increases the likelihood that more immediate adaptation actions will also enhance future options and preparedness. {3.3}

There are multiple mitigation pathways that are likely to limit warming to below 2º C relative to pre-industrial levels. These pathways would require substantial emissions reductions over the next few decades and near zero emissions of CO2 and other long-lived greenhouse gases by the end of the century. Implementing such reductions poses substantial technological, economic, social and institutional challenges, which increase with delays in additional mitigation and if key technologies are not available. Limiting warming to lower or higher levels involves similar challenges but on different timescales. {3.4}

Many adaptation and mitigation options and help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales and can be enhances through integrated responses that link adaptation and mitigation with other societal objectives. {4}

Adaptation and mitigation responses are underpinned by common enabling factors. These include effective institutions and governance, innovation and investments in environmentally sound technologies and infrastructure, sustainable livelihoods and behavioural and lifestyle choices. {4.1}

Adaptation options exist in all sectors, but their context for implementation and potential to reduce climate-related risks differs across sectors and regions. Some adaptation responses involve significant co-benefits, synergies and trade-offs. Increasing climate change will increase challenges for many adaptation options. {4.2}

Mitigation options are available in every major sector. Mitigation can be more cost-effective if using an integrated approach that combines measure to reduce energy use and their greenhouse gas intensity of end-use sectors, decarbonize energy supply, reduce net emissions and enhance carbon sinks in land-based sectors. {4.3}

> Effective adaptation and mitigation responses will depend on policies and measure across multiple scales: international, regional, national and sub-national. Policies across all scales supporting technology development, diffusion and transfer, as well as finance for responses to climate change, can complement and enhance the effectiveness of policies that directly promote adaptation and mitigation. {4.4}
>
> Climate change is a threat to sustainable development. Nonetheless, there are many opportunities to link mitigation, adaptation and the pursuit of other societal objectives through integrated responses *(high confidence)*. Successful implementation relies on relevant tools, suitable governance structures and enhance capacity to respond *(medium confidence)*. {3.5, 4.5}

(Pachauri et al. 2014)

The findings from the 2014 Synthesis Report highlight the physical science basis for climate change, the anthropogenic role in greenhouse gas emissions in changing the climate, and the role of development in enhancing or attenuating greenhouse gas emissions among many socio-environmental findings.

Greenhouse Gases

There are six major gases (or classes of gas in the case of fluorinated gases and hydrofluorinated gases) which have been identified as contributing to changes in the climate. The six major greenhouse gases may be broken into two main categories, those which naturally occur, and the halogenated species, which are the product solely of human activity and did not exist in any concentration in the atmosphere until recently. Of the naturally occurring greenhouse gases, carbon dioxide, methane, and nitrous oxide, there has been a dramatic increase in their concentration in the atmosphere to levels higher than any other point in the last 800,000 years (Pachauri et al. 2014). Carbon dioxide in particular has seen its concentration increase by half in just the last 42 years (Pachauri et al. 2014).

The measurement of emissions in either per capita, per unit of GDP, or total emissions are all commonly used in comparative research. Generally, the research question drives which version of greenhouse gas emission is included as the dependent variable. For this research project, I investigate the explanatory power of four major bodies of social theory on all six of the greenhouse gases identified as responsible for climate change by the IPCC. Among these greenhouse gases, four have never been analyzed sociologically, and per capita transformations for these variables are not readily available. This does not pose a major methodological concern, as this research seeks to compare and contrast the relative success for each theory in predicting each of the greenhouse gases, understanding how total emissions are affected across both the naturally occurring and halogenated species is better achieved with outcome variables which are comparable. In this case, each greenhouse gas (except carbon dioxide) are in CO_2 equivalent metric tons, allowing researchers the ability to assess a given theory's relative explanatory power in a comparative way for each greenhouse gas.

Carbon Dioxide emissions are by far the most well studied greenhouse gas in this group (Burns et al. 1997; Ergas and York 2012; Glaeser and Kahn 2008; Jorgenson and Clark 2010, 2013; Jorgenson 2011, 2012; Knight and Schor 2014; Liddle and Lung 2010; Mckinney 2012; Qu and Zhang 2011; Roberts et al. 2003; Shandra et al. 2004). This overemphasis on carbon dioxide may be rightfully so, considering the better data coverage relative to other greenhouse gas emissions and the higher concentration of carbon dioxide in the atmosphere as compared to the rest of the major greenhouse gases, making up over 70% of the overall greenhouse gas concentration (International Energy Agency 2012, Myhre et al. 2013). Methane emissions, make up about 20% of the overall greenhouse gas concentration, nitrous oxide making up about 8% of the concentration, and the halogenated species combined comprising just 25 of the total greenhouse gas concentration (International Energy Agency 2012, Myhre et al. 2013).

Unfortunately, this fixation on carbon dioxide relative to other greenhouse gas emissions may have led to a monolithic view of the anthropogenic drivers of climate change. Worldwide, the single greatest source of carbon dioxide emissions comes from the burning of fossil fuels, most especially coal. Carbon dioxide emissions also come from cement production, refineries, steel mills, and the petrochemical industry (Gale et al. 2011).

Receiving less scrutiny than carbon dioxide in the social science literature, methane emissions are the next most prevalent greenhouse gas contributing to global warming (Jorgenson 2006; Marten and Newbold 2012). Despite having lower atmospheric concentrations, methane concentrations have increased 150% since industrialization, and projections based on no change in growth and emissions predict methane concentrations will again double by 2016 (Myhre et al. 2013). It is estimated that 60% of methane concentrations come from human activity, and each ton of methane (carbon dioxide equivalent) has a global warming potential of 28, meaning that pound for pound, methane has 28 times the impact over a 100-year period than the same unit of carbon dioxide (Blasing 2014). Methane emissions sources from anthropogenic include coal mining, oil and natural gas, landfill and waste off-gassing, ruminant agriculture, rice cultivation, and biomass burning (Denman et al. 2007a).

The surface concentration of nitrous oxide has increased 19% since 1750; this increase comes overwhelmingly from fossil fuel dependent human activity (Myhre et al. 2013). The increase seen over this time period is overwhelmingly attributed to human activities, and large increases are reported in the last 20 years. This recent increase has led to the IPCC classifying nitrous oxide as the third highest greenhouse gas contributor to radiative forcing in the atmosphere (Myhre et al. 2013). Like methane, nitrous oxide has a higher global warming potential relative to carbon dioxide, where each ton of carbon dioxide equivalent nitrous oxide has 265 times the radiative effect (Blasing 2014). The primary anthropogenic sources for nitrous oxide emissions come from fossil fuel combustion and industrial manufacturing, agriculture, and biomass burning (Denman et al. 2007b).

Hydrofluorocarbon gas emissions, perfluorinated carbon gas emissions, and sulphur hexafluoride gas emissions represent a class of emissions the Intergovernmental Panel on Climate Change defines as halogenated species. These gases have little to no naturally occurring sources, and when the gases contain chlorine or bromine, they interact with stratospheric ozone, depleting it (Myhre et al. 2013). Hydrofluorocarbon gas emission sources include refrigerants used in air conditioners and refrigerators, foam blowing, solvents used in cleaning, and aerosol propellants (McCulloch 1994). Hydrofluorocarbon and perfluorinated carbon gases have global warming potentials ranging from 782 to 10,200 times the impact as carbon dioxide equivalent tons (Blasing 2014). The sources of perfluorinated gases include the production of aluminum and the manufacture of semiconductors (Watson et al. 1992a). The single largest global warming potential comes from sulphur hexafluoride, where a single unit is equivalent to 23,500 comparable units of carbon dioxide (Blasing 2014). Sulphur hexafluoride emission sources include its use in the electric power industry as an insulator and arc interrupter and its use in magnesium production (Watson et al. 1992b). Even with relatively low levels of theses halogenated gases in the atmosphere, their impact on radiative forcing is large, and clearly demonstrates the need to include analyses of these gases when studying the anthropogenic factors that drive greenhouse gas emissions.

Chapter 3: Data and Methods

Guiding this research into each of the classes of greenhouse gas emissions identified as the key drivers of climate change is quest to understand the efficacy of each of the theoretical perspectives ability to predict the societal mechanisms which drive each class of emissions. The data I use to investigate how large scale societal processes involved in development may be altered to better account for and attend to their inherence ecological consequences come from the World Bank's World Development Indicators (2015). Understanding the various social structural processes which drive each class of emissions will allow for a more accurate picture of the ways in which societies, and international groups may allocate resources to best incorporate sustainability into the structures of society. Previous research has focused predominately on carbon dioxide, and with good reason. Carbon dioxide is the most prolific of the classes of greenhouse gases, with the longest history of large scale emissions dating to the advent of the industrial revolution. The predominance of social research into the drivers of carbon dioxide emissions has led some to apply the same theoretical lens against the rest of the classes of greenhouse gas emissions, perhaps inadvertently proposing solutions that may in fact fail to reduce those emissions, and at worst, increasing their emission rates by encouraging policy which reduces carbon dioxide in favor of increasing emissions from the other classes of greenhouse gas emissions.

Methods

I employ Ordinary Least Square regression analysis to investigate competing theories regarding the relationship between societal structures and each of the major classes of greenhouse gas emissions, including the naturally occurring greenhouse gases carbon dioxide, methane, and nitrous oxide gas emissions, and the halogenated species of greenhouse gases hydrofluorocarbon, perfluorinated, and sulphur hexafluoride gas emissions. I investigate direct effects models in this research project for reasons related to the limitations created by the relatively small sample sizes available for the understudied greenhouse gases. By focusing on direct effects for the key variables identified by each of the theoretical perspectives under study, I am able to establish key differences between the classes of greenhouse gas emissions in their respective structural drivers. Since the introduction of the halogenated species of greenhouse gases is novel in sociological research, providing baseline models measuring direct effects represents the first steps in uncovering the theorized structures which affect emissions.

Cross-national comparative research often employs OLS as the method of choice for examining structural level effects on greenhouse gas emissions (Glaeser and Kahn 2008; Jorgenson 2006; Roberts et al. 2003). For all dependent variables I measure total emissions in carbon dioxide equivalent amounts and these data all come from the World Bank (2015). Many of the independent variables are also drawn from the World Development Indicators from the World Bank (2015), with the exception of the world-system position indicators from Kick et al. (2011), and the world polity indicators which come from the Polity IV project from the Center for Systemic Peace

(2014). National level indicators are often subject to issues regarding multicollinearity, for each model I include the mean and high variance inflation factor scores. Additionally, research has shown that the use of composite scores in comparative research is a supportable strategy (Davis, Kick, and Burns 2004).

I include as many cases in each analysis as data availability allows, given the nature of national level datasets the sample size fluctuates between dependent variables considerably in my effort to maximize available data. Cases with missing data are excluded list-wise. The decreasing sample size with the halogenated species of greenhouse gas emissions is troubling in the sense that results may not truly reflect differences influenced by the independent variables, decreasing the reliability of those results (Knoke, Bohrnstedt, and Mee 2002). As data coverage for these halogenated emissions variables grow in the coming years, sample sizes will increase, much like data coverage for carbon dioxide has increased and improved since the earliest sociological investigations began into their emissions. The robustness of inferences made among the halogenated species results are bolstered by their relative alignment across this class of emissions, and future research will further serve to reinforce these findings. Although imperfect, this research is a critical first step in understanding the unstudied greenhouse gases and the structures which affect their emissions, although not ideal in number, the samples represent the important genesis of the inclusion of the halogenated species in sociology.

Dependent Variables

The greenhouse gas emission variables I employ in these analyses include all of the major species of greenhouse gases identified by the Intergovernmental Panel on

Climate Change as contributing to climate change (Intergovernmental Panel on Change 2007; Hartmann et al. 2013; Myhre et al. 2000; Watson et al. 1992). Carbon dioxide, methane, nitrogen oxide, and the halogenated species including Hydrofluorocarbon gases, perfluorinated carbon gases, and sulphur hexafluoride are each analyzed in a comparative framework examining the relative explanatory power of each of the major social structural explanations for increased emissions. Per capita emissions are a popular method for analyzing carbon dioxide emissions in particular, but increase issues with multicollinearity and potentially bias results (Ergas and York 2012; Jorgenson 2011, 2012). I choose to utilize total emissions (carbon dioxide equivalent for the non-CO2 greenhouse gases) for methodological reasons and to maximize the explanatory power for the understudied greenhouse gas emissions, total emissions allows for better comparisons across greenhouse gases.

Carbon dioxide emissions data come from nations reporting fossil fuel consumption, cement manufacture, and the production of gas produced in the consumption of solid, liquid, and gas fuels and flares. Methane emissions, from national level reporting of agricultural production and industrial sources come from the European Commission, Joint Research Centre through the Emission Database for Global Atmospheric Research. The data for nitrous oxide are calculated through country level reporting of agricultural biomass burning, industrial activities, and livestock management and compiled by the European Commission, Joint Research Centre through the Emission Database for Global Atmospheric Research. These data for the naturally occurring gases are estimates based on self-reporting, and analyses conducted by the Emission Database for Global Atmospheric Research. Emissions data for all greenhouse gases align to UNFCCC and IPCC reporting guidelines and the commissions involved work closely to ensure accuracy, consistency, comparability, and transparency of reports (United Nations Framework Convention on Climate Change 2004).

Reporting for the halogenated species is less reliable than the naturally occurring species, as their reporting and atmospheric concentrations have a longer history and larger concentration in the atmosphere (International Energy Agency 2012). Hydrofluorocarbon data are estimated based on consumption of hydrofluorocarbons used in refrigeration and semiconductor manufacturing. Perfluorinated gas emission data are based on national level reporting of the manufacture of semiconductors, aluminum smelting, and uranium enrichment. The data for sulphur hexafluoride emissions estimates are based reporting of high voltage electric power equipment usage in electricity generation and distribution. All of the data for the halogenated species are collected by the European Commission with the Joint Research Center and the Netherlands Environmental Assessment Agency Emission Database for Global Atmospheric Research. The variables for distributing global consumption per emissions category are relatively uncertain, but represent the good faith efforts of the international commissions collaborating to create emissions totals, particularly for fluorinated gases, for which country level data is estimated based on both the production and consumption of fluorinated gas emitting industry (International Energy Agency 2012).

Every effort is made by the organizing commissions to ensure country level estimates are as accurate as possible, but the data by nature are not fully representative by nature of being self-reported. Nations may inadvertently under report or over report emissions, as was the case in China, where carbon dioxide emissions were over reported for several years due to conflicting reports of coal consumption (Liu et al 2015). Although certainly not perfect, these data represent the best possible estimates available for greenhouse gas emissions, and results must be interpreted with caution due to the potential issues of reliability due to reporting, and representativeness.

Independent Variables

As this research is investigating the relative explanatory power of four distinct theoretical frameworks for understanding the human impact on the environment at the societal level the independent variables under study reflect the diversity of these perspectives.

Population 2010

Population size matters, and has been historically demonstrated to worsen environmental harms, particularly with regard to environmental measures such as greenhouse gas emissions (Dietz and Rosa 1997; Rosa et al. 2004; York et al. 2003; York and Rosa 2012; York et al. 2003). Here I utilize population in 2010 from the World Development Indicators dataset, logged to account for kurtosis (World Bank 2015).

Gross Domestic Product per Capita 2010

Gross Domestic Product per Capita is a widely used measure for approximating a nation’s level of development and affluence relative to peer nations. Gross domestic product per capita is widely accepted as the best indicator for a nation’s level of wealth (Clark 2011; Crenshaw and Robison 2010; Firebaugh 1996, 1999; Jorgenson et al.

2014; Liddle and Lung 2010; York et al. 2003b). The World Development Indicators provide these data for analysis and I logged the data due to excessively kurtotic distribution (World Bank 2015).

Quadratic transformation of Gross Domestic Product per Capita 2010

Affluence has been theorized by proponents of the Environmental Kuznets Curve to operate in a curvilinear fashion, where initial economic development is associated with increasing harms until a certain level is reached, and further increases in affluence see decreasing harms to the environment. The Environmental Kuznets Curve has been demonstrated with a variety of dependent variables including ecological footprint, deforestation, and energy intensity (Ehrhardt-Martinez et al. 2002; Kaika and Zervas 2013; Torras and Boyce 1998; York et al. 2005). In keeping with this body of literature, I include a quadrative transformation of gross domestic product per capita centered by the mean of gross domestic product per capita, logged for kurtosis (World Bank 2015).

Urban Population 2010

While population in and of itself is theorized to impact environmental outcomes, specifically those associated with greenhouse gas emissions, not all populations exhibit the same level of intensity with regard to those impacts. Urbanization, or the share of the nation's population which resides in urban areas has been demonstrated to exact a strong impact in analyses of environmental harms, especially with regard to carbon dioxide (Assadourian 2012; Ehrhardt-Martinez et al. 2002; Ergas and York 2012; Jorgenson et al. 2014; Liddle and Lung 2010). Urbanization data come from the World Development Indicators database (World Bank 2015).

Non-Dependent Population 2010

The percent of the population that is working age has been demonstrated in prior research to exhibit a greater impact on environmental outcomes including carbon dioxide emissions and deforestation (Jorgenson et al. 2014; Shandra et al. 2009). To better understand the effects of the working age population on the understudied greenhouse gas emissions I include non-dependent population from the World Bank (2015).

Percent of Exports to High Income Countries 2010

The percent of exports to high income countries comes from the World Development Indicators database and represents the total for merchandise exports from the originating country to a group of nations classified by the World Bank as high income based on national income (World Bank 2015). Jorgenson (2012) found that this measure correlated above .90 with previous attempts to quantify ecologically unequal exchange utilizing weighted export flows. For the purposes of this research project, utilizing the World Bank indicator provides a more readily interpreted indicator with better country coverage than alternative attempts to operationalize ecologically unequal exchange.

Percent of Exports to High Income Countries X Lower Income Countries 2010

For the purposes of modelling the differential effect of exports originating from lower income countries versus relatively more affluent countries and the impact on greenhouse gas emissions relative to this difference in exporting countries, I also include an interaction variable in this research. Utilizing the World Bank classification schema I created a dummy variable for lower income countries defined by the World

Bank as those nations with Gross National Incomes per capita of less than $12,735, the reference group are high income countries. Models containing this interaction variable allows me to better model the true impact of ecologically unequal exchange, where less affluent nations are more dependent upon these exports, even when the natural resources extraction coupled with the manufacturing process create a greater burden on the environment through increased greenhouse gas emissions (2015).

World System Position 1995-1999

World system position is included as an independent variable in this analysis in a series of dummy variables where core nations are the excluded category and resulting in a series of block dummy positions where higher number label indicate distance from the core. These data come from Kick et al. (2011) and the blockmodel country lists are provided in the Appendix A. World system position has been shown to affect environmental outcomes, and is a strong indicator for ecologically unequal exchange (Burns et al. 1997; Ergas and York 2012; Mckinney 2012; Roberts et al. 2003). This variable greatly affects sample sizes in the ensuing analyses, limiting the potential robustness of this study. These sample effects are felt most acutely among the halogenated species of greenhouse gases, for which sample sizes are already lower than the naturally occurring species. Despite the impact on sample size, the world-system position block models have previously demonstrated an effect on carbon dioxide emissions and warrant investigation to determine whether those effects are also demonstrable with the understudied greenhouse gases.

Polity IV Index 2010

Democracy is theorized in world polity approaches to provide the freedom and openly available mechanisms where the people may voice concerns and change policy (Ergas and York 2012; John M. Shandra et al. 2009; Zhou 2012). Utilizing the Polity IV index, a widely accepted scale which measures nations on a scale of -10 (highly autocratic) to +10 (highly democratic) where larger scores indicate greater democracy and therefore more robust civil society (Marshall, Gurr, and Jaggers 2014).

International Non-Governmental Organizations 2010

Data for international nongovernmental organization presence come from the Polity IV dataset (Marshall et al. 2014) and measure the number of non-governmental organizations present within a given country. These data model the civil society which operates to achieve goals on behalf of an engage populace and has been shown to exert an effect on a variety of environmental outcomes (Jorgenson and Clark 2011; Jorgenson et al. 2011; Pellow and Nyseth Brehm 2013; Rudel et al. 2011; John M. Shandra et al. 2009).

Hypotheses

H_1: The structural human ecology approach predicts higher population exhibits a positive relationship to greenhouse gas emissions.

> H_{1a}. The structural human ecology perspective predicts higher levels of affluence are associated with increased greenhouse gas emissions.
>
> H_{1b}: Structural human ecology predicts a positive relationship between urbanization and greenhouse gas emissions.
>
> H_{1c}: Human ecology predicts a positive relationship between higher non-dependent population and greenhouse gas emissions.

H_{1d}: Affluence has a curvilinear relationship with greenhouse gas emissions.

H_2: Ecologically Unequal Exchange predicts a positive relationship between greater export intensity to high income countries with greenhouse gas emissions.

H_{2a}: Lower Income countries are predicted by ecologically unequal exchange theory to exhibit a strong linear relationship between exports to high income countries and greenhouse gas emissions.

H_{2b}: World-systems theory predicts that countries in blocks more distant from the core will exhibit a positive linear relationship to greenhouse gas emissions.

H_3: World Polity theory predicts nations with higher levels of democracy will exhibit an inverse relationship to greenhouse gas emissions.

H_{3a}: Civil Society theory predicts an inverse relationship between the number of international non-governmental organizations and greenhouse gas emissions.

Chapter 4: Naturally Occurring Greenhouse Gas Emissions

Carbon Dioxide Outcomes

The results for Carbon Dioxide align well with previous research on the structural drivers for emissions are presented in Table 1. With these results, I confirm hypotheses H_1, H_{1a}, and H_{1c}, and H_{1d} population, affluence, non-dependent population, and the quadratic form of affluence exhibit statistically significant relationships to carbon dioxide emissions. I fail to confirm hypotheses H_{1b}, and there is no evidence for a statistically significant relationship between urbanization and carbon dioxide emissions. The results for Ordinary Least Squares analysis shows the strong predictive power of the structural human ecology perspective for carbon dioxide across all models, with an r^2 consistently above .904 across models. Model 1 provides the most parsimonious evidence for the structural human ecology perspective, where population and gross domestic product per capita alone exhibit a strong, positive, linear relationship to carbon dioxide emissions, accounting for over 90% of the variance in carbon dioxide emissions.

Table 1. Results for Ordinary Least Squares Regression to investigate Structural human ecology theories of carbon dioxide emissions.

Model 1		Model 2		Model 3		Model 4	
b	β	*b*	β	*b*	β	*b*	β
		-0.0002 (0.001)	-0.004			-0.0002 (0.001)	-0.005
		0.036*** (0.004)	0.249			0.029*** (0.004)	0.201
1.052*** (0.028)	0.870	1.047*** (0.027)	0.820	1.073*** (0.025)	0.888	1.066*** (0.025)	0.836
0.892*** (0.037)	0.561	0.627*** (0.056)	0.404	3.509*** (0.034)	0.569	0.683*** (0.052)	0.441
				-0.365*** (0.046)	-0.158	-0.264*** (0.045)	-0.115
-6.251*** (0.250)		-7.571*** (0.287)		-6.259*** (0.217)		-7.327*** (0.266)	
1.031		2.188		1.092		1.957	
1.031		3.214		1.154		3.469	
.904		.929		.928		.941	
181		181		181		181	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

		Urban Population	Non-Dependent Population	Population (logged)	GDP per capita (logged)	(GDP per capita (logged))^2	Constant	Mean VIF		R^2	N	

Investigating the simple scatterplots for population and gross domestic product per capita and carbon dioxide provide visual evidence for the linear character of the structural human ecology perspective as it relates to carbon dioxide emissions. Model 1 also exhibits very low variance inflation factors relative to models 2, 3, and 4. Multicollinearity is a major methodological concern in international comparative sociological research, and the explanatory advantages of Model 1 are further bolstered by the relatively low collinearity for the independent variables included in the model.

Model 2 in Table 1 confirms hypothesis H_{1c}, the effect of the age dependency ratio relative to carbon dioxide emissions, but failed to confirm H_{1b}, or the role of urbanization in carbon dioxide emissions. Model 2 supports previous analyses of the role of population on carbon dioxide emissions where the role of population is best understood for its variety than simply population or population's sake. In other words, not all populations increase greenhouse gas emissions alike, indeed, a higher non-dependent population seems to bear the responsibility for increasing carbon dioxide emissions. Although not statistically significant, urban population exhibits what may be an attenuating effect on carbon dioxide emissions, with a negative coefficient. I find in Model 2, that the population and affluence variables decline in effect, where their coefficients drop slightly, but the variable for the percent of the population that is non-dependent is positive and statistically significant ($p<.001$) and the r^2 increases slightly to .929. The variance inflation factors increase in model 2, but still fall within an acceptable range considering the closely coupled nature of the variables under investigation.

Model 3 in Table 1 investigates the potential of a curvilinear relationship between affluence and carbon dioxide emissions. Specifically, it is theorized that as a society develops and modernizes there comes a point in development where additional gains in affluence, rather than further increasing emissions, would instead result in decreasing carbon dioxide emissions through efficiencies gained as society modernizes. The potentially negative effect of urbanization on carbon dioxide emissions would lead a theorist to investigate the character of the relationship between these key variables. In estimating the curvilinear relationship I included the quadratic transformation for affluence, in Model 3 we see that I confirmed hypothesis H_{1d}. I find that the relationship of gross domestic product per capita with carbon dioxide emissions reflects a curvilinear relationship. Indeed, the results presented in Table 1, Model 3 indicate that gross domestic product per capita increases carbon dioxide emissions, the coefficient for which is positive and statistically significant ($p<.001$). The coefficient for the quadratic transformation of gross domestic product per capita variable is negative, and also statistically significant ($p<.001$) indicating a curvilinear relationship between affluence and carbon dioxide emissions when controlling for population.

I investigate a fully saturated structural human ecology approach in Model 4, and find results consistent with Models 1, 2, and 3. In Model 4, we see that the effects of the non-dependent population, population, gross domestic product, and the quadratic transformation of gross domestic product all remain statistically significant, even while controlling for all of the structural human ecology variables. Model 4, unsurprisingly, exhibits the highest collinearity issues of the models presented in Table 1, with a modestly higher mean variance inflation factor of 3.469, the variance inflation factors still fall within acceptable limits for interpretation of the explanatory power of the structural human ecology approach to greenhouse gas emissions. The r^2 is also highest in Model 4, although may not be significantly enough higher than Model 1 to make the fully saturated model the best possible set of variables for explaining the variation in carbon dioxide emissions parsimoniously. The results for the efficacy of structural human ecology theories for explaining the variance in carbon dioxide emissions provide a compelling case for the importance of population as a structural factor for driving emissions.

Table 2 presents the results for investigating the efficacy of the theory of ecologically unequal exchange on carbon dioxide emissions. The results confirm hypotheses H_{2b}, I fail to confirm hypotheses H_2 and H_{2a} in the results presented in Table 2.

Table 2. Results for Ordinary Least Squares Regression to investigate Ecologically Unequal Exchange theories of carbon dioxide emissions.

Model 2		Model 3	
b	β	*b*	β
1.066*** (0.030)	0.868	1.087*** (0.049)	0.786
0.762*** (0.065)	0.496	0.948*** (0.062)	0.694
0.001 (0.002)	0.010	-0.002 (0.001)	-0.046
-0.004** (0.001)	-0.117		
		0.101 (0.148)	0.033
		0.475** (0.175)	0.135
		0.434* (0.175)	0.113
		0.743*** (0.176)	0.240

Table 2. Continued.

	Model 1		Model 2		Model 3	
	b	β	*b*	β	*b*	β
WSP 7					0.477** (0.177)	0.119
WSP 8					0.375* (0.163)	0.154
WSP 9					0.157 (0.196)	0.069
WSP 10					0.516** (0.196)	0.135
Constant	-6.305*** (0.273)				6.909*** (0.590)	
Mean VIF	1.217		2.059		4.223	
Highest VIF	1.321		3.105		10.601	
R^2	.897		.903		.917	
N	174		174		142	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

	Model 1	
	b	β
Population (logged)	1.064*** (0.031)	0.867
GDP per capita (logged)	0.916*** (0.043)	0.597
Exports to High Income Countries	-0.002 (0.001)	0.001
Exports to High Income Countries X Low Income Countries		
WSP 2		
WSP 3		
WSP 5		
WSP 6		

Model 1 in Table 2 provides the baseline model indicated by theories of ecologically unequal exchange, where the percentage of exports to high income countries is expected to exhibit a positive, linear, statistically significant relationship to carbon dioxide emissions when controlling for population and affluence. While export concentration to high income countries has been shown to exhibit a positive relationship to carbon dioxide emissions intensity (emissions measured as per capita as opposed my preferred measure of emissions total), the relationship does not seem to persist when the outcome variable is total greenhouse gas emissions. Due to the relatively small number of variables included in Model 1, the mean variance inflation factors are the lowest among all models in Table 2.

Model 2 in Table 1 presents the results for the interaction variable taking exports to high income countries from low income countries in addition to the pure exports to high income countries variable, and the control variables for population and affluence. The results for these two variables when controlling for population and affluence is counterintuitive when investigating the potential explanatory power to ecologically unequal exchange. Although the variable modeling exports to high income countries continues to lack statistical significance, the interaction variable of exports to high income countries from low income countries does reach the threshold of significance, but displays an inverse relationship to carbon dioxide emissions. The coefficient for exports to high income countries flips signs, and unlike Model 1, now shows a potentially positive effect on carbon dioxide emissions. The R^2 for Model 2 increases only marginally, from .897 in Model 1, to .903 in Model 2. The results of Model 2 demand additional scrutiny of ecologically unequal exchange, to better tease out the true relationships between nations regarding unequal exchange and carbon dioxide emissions.

The results for ecologically unequal exchange by world-system position are presented in Model 3 of Table 2 and confirm hypothesis H_{2b}. Utilizing world-system position, I find overall the more distant blocks (from the core) exhibit positive, statistically significant, linear relationships to carbon dioxide emissions. Specifically, I find world-system position blocks 3, 5, 6, 7, 8, and 10 are all positive and statistically significant (with p values ranging from .001 to .05). Result indicates that distance from the core from a world-system perspective increases carbon dioxide emissions while controlling for population, affluence, and exports to high income countries. Model 3 enjoys the highest R^2 in Table 2 at .917, but is accompanied by the greatest collinearity among the models, with a mean variance inflation factor of 4.223.

The results for World Polity Theory are presented in Table 3 where I confirm hypotheses H_3 and H_{3a}.

Table 3. Results for Ordinary Least Squares Regression to investigate World Polity and Civil Society theories of carbon dioxide emissions.

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	1.065*** (0.039)	0.755	1.157*** (0.045)	0.787
GDP per capita (logged)	0.939*** (0.041)	0.669	1.051*** (0.045)	0.770
Polity IV	-0.015** (0.005)	-0.092	-0.011* (0.005)	-0.073

INGOs			-0.009*** (0.002)	-0.166
Constant	-6.445*** (0.323)		-7.072*** (0.352)	
Mean VIF	1.066		1.419	
Highest VIF	1.099		1.745	
R^2	.884		.896	
N	156		148	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

Model 1 presents the basic world polity conception of the key structural driver for carbon dioxide emissions, a nation's level of democracy, while controlling for population and affluence. In this model a nation's level of democracy displays an inverse, statistically significant (p<.01) linear relationship with carbon dioxide emissions and while controlling for the key structural variables of population and affluence, explains 88% of the variance in carbon dioxide emissions. Model 1 exhibits smaller variance inflation factors relative to Model 2. Model 2 further investigates the role of civil society on carbon dioxide emissions by including the extent of the presence of international non-governmental organizations' effect on carbon dioxide emissions. I find that both democracy and international non-governmental organization presence exhibit inverse relationships to carbon dioxide emissions (p<.05 and p<.0, respectively). The effect of democracy seems somewhat attenuated by controlling for international non-governmental organization presence. Variance inflation factors remain low in Model 2. with a mean VIF of 1.419 and increases the R^2 slightly from Model 1 to .896.

Carbon Dioxide Discussion

Across all theoretical models implemented for examining structural drivers for carbon dioxide emissions, the structural human ecology perspective provides some of the best predictors for increasing greenhouse gas emissions. While this information is critical to addressing carbon dioxide emissions, it does not fully paint the picture of structural drivers for carbon dioxide emissions, specifically, it does not uncover which mechanisms may enhance this positive relationship, and which variables may exert a dampening effect on carbon dioxide emissions. Including analyses for ecologically unequal exchange theory and world polity theory better elaborates the relationships between national level factors and greenhouse gas emissions. A fully saturated model including all of the theoretical models for carbon dioxide is presented in Table 28 in the appendix.

Rather than any one perspective emerging as the sole explanatory framework for greenhouse gas emissions, these analyses indicate that certain factors (specifically, a nation's distance from the core in a world-systems framework) increases carbon dioxide emissions even when controlling and considering structural human ecology drivers of population and affluence, and civil societal factors help decrease emissions. The inverse relationship between civil society and carbon dioxide emissions is promising in light of the possible climate change policy adaptations, specifically it highlights the potential for democratic nations, and those with robust civil society to adapt and adopt policy to reduce emissions.

Methane Outcomes

The results investigating the explanatory power of structural human ecology theory on methane emissions presented in Table 4 follow patterns across models similar to the research I conducted on carbon dioxide.

Table 4. Results for Ordinary Least Squares Regression to investigate Structural human ecology theories of methane emissions.

Model 1		Model 2		Model 3		Model 4	
b	β	*b*	β	*b*	β	*b*	β
		-0.002 (0.002)	-0.051			-0.001 (0.002)	-0.046
		0.015** (0.005)	0.155			0.015** (0.005)	0.148
0.904*** (0.043)	0.870	0.909*** (0.042)	0.914	0.859*** (0.055)	0.863	0.881*** (0.054)	0.886
0.139** (0.043)	0.561	0.086 (0.072)	0.086	0.138** (0.045)	0.138	0.080 (0.079)	0.080
				-0.046 (0.063)	-0.032	0.0004 (0.066)	0.0003
-2.758*** (0.385)		-3.497*** (0.444)		-2.437 (0.456)		-3.261*** (0.535)	
1.080		2.096		1.092		1.957	
1.080		3.137		1.154		3.469	
.776		.792		.928		.941	
131		131		131		131	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

		Urban Population	Non-Dependent Population	Population (logged)	GDP per capita (logged)	(GDP per capita (logged))^2	Constant	Mean VIF		R^2	N	

Model 1 in Table 4 presents the leanest model, examining the impact of population and affluence measured as gross domestic product per capita on methane emissions, both of which net statistically significant coefficients ($p<.001$ and $p<.01$ respectively) with a reasonably high R^2 of .776. Model 1 provides a theoretically and statistically sufficient explanation for a great deal of the variance in methane emissions cross nationally. Model 1 confirms hypothesis H_1 and H_{1a}.

Model 2 in Table 4 investigates the types of populations theorized by human ecologists to exhibit greater relative impacts on methane emissions. In Model 2 I confirm hypothesis H_{1c}. When including variables for urbanization and the percent population classified as non-dependent, I find that gross domestic product per capita loses statistical significance, while the unstandardized coefficient for the non-dependent population independent variable of 0.015 is statistically significant and exhibits a positive relationship to methane emissions ($p<.01$). Urbanization fails to meet the threshold of statistical significance, therefore I fail to confirm hypothesis H_{1b}.

Model 3 investigates the potentially curvilinear relationship between affluence and methane emissions and although the coefficient for gross domestic product per capita has an opposite sign, the quadratic transformed variable fails to meet the threshold of significance. Methane emissions, although heavily influenced by population and affluence, are remarkably different in character than carbon dioxide emissions, where affluence fails to exhibit a nonlinear relationship to methane emissions and I fail to confirm hypothesis H_{1d}. More troubling than the absence of curvilinearity in Model 3 is the drop in R^2 from .792 in Model 2 to only .780 in Model 3.

Model 4 presents the fully saturated structural human ecology model, and in it I confirm hypothesis H_1, and H_{1c} and fail to confirm hypotheses H_{1a}, H_{1b}, and H_{1d}. When controlling for all population and affluence variables, total population, and the percent non-dependent have a positive linear relationship with methane emissions and Model 4 has an R^2 of .793. I find that total population is strongly associated with methane emissions relative to other structural human ecology variables, statistically significant ($p<.001$). The age dependency ratio also factors heavily in methane emissions when controlling for population and affluence, and indicates that not all populations exert the same effect on methane emissions, instead, the larger the non-dependent population is, the greater the impact on methane emissions ($p<.01$). From a structural human ecology perspective, methane emissions are more difficult to predict, but above all, population remains a key factor for increasing emissions.

In Table 5 I present the findings for ecologically unequal exchange theory and methane emissions. When controlling for all variables, I confirm hypothesis H_{2b} and fail to confirm hypotheses H_2 and H_{2a}.

Table 5. Results for Ordinary Least Squares Regression to investigate Ecologically Unequal Exchange theories of methane emissions.

Model 3	
b	β
0.980*** (0.066)	1.012
0.265*** (0.077)	0.278
0.001 (0.002)	0.751
0.111 (0.154)	0.060
0.274 (0.158)	0.132
0.465* (0.188)	0.197
0.431* (0.198)	0.235

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	0.909*** (0.045)	0.910	0.912*** (0.045)	0.913
GDP per capita (logged)	0.142** (0.052)	0.142	0.089 (0.075)	0.089
Exports to High Income Countries	-0.0004 (0.002)	-0.011	0.0004 (0.002)	0.011
Exports to High Income Countries X Low Income Countries			-0.002 (0.002)	-0.064
WSP 2				
WSP 3				
WSP 5				
WSP 6				

Table 5. Continued.

Model 1	Model 2		Model 3	
β	*b*	β	*b*	β
			0.037 (0.190)	0.016
			0.337 (0.177)	0.215
			0.450* (0.207)	0.239
			0.629** (0.221)	0.220
			-4.154*** (0.774)	
1.299	2.000		3.913	
1.456	3.031		6.674	
. 773	. 775		.808	
127	127		113	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

	b
WSP 7	
WSP 8	
WSP 9	
WSP 10	
Constant	-6.305*** (0.273)
Mean VIF	
Highest VIF	
R^2	
N	

Model 1 in Table 5 specifically investigates the predictive power of exports to high income countries as a measure of dependency in an ecologically unequal exchange framework and find that the control variables for population and affluence are positive and statistically significant (P<.001 and p< .01 respectively). Model 1 has the lowest R^2 among ecologically unequal exchange models at .773.

Model 2 in Table more specifically investigates the role of exports to high income countries with the addition of an interaction variable to disaggregate the effects of trade from low income countries to high income countries specifically. In Model 2 I find a negligible increase in R^2 to .775, and the variables for gross domestic product per capita, exports to high income countries, and exports to high income countries interaction variable all fail to meet the threshold of significance. When controlling for those variables, only population remains a significant explanatory factor for the variance in methane gas emissions (p<.001).

The third model presents the results of an investigation into world-system position as it effects methane emissions. I find that both of the control variables for population and affluence are positive and statistically significant (P<.001), but the exports to high income countries variable continues to lack predictive power. The R^2 increases over Models 1 and 2 to .808 when including the world-system position variables. I find the relationship between world-system position and methane gas emissions to fall in line with theories of ecologically unequal exchange from a world-system perspective, where increased distance from the core increases ecological burdens, in this case, methane emissions. Specifically, the dummy variables for world-system position in blocks 5, 9, and 10 are all positive and statistically significant ($p<.05$), and block 3 approaches significance, with a p value of .086. While these results are promising for ecologically unequal exchange they are viewed with some caution as the mean variance inflation factor increases to 3.913 indicating greater collinearity due to the nature of the world-system position block variables.

I present the results for Ordinary Least Squares regression analysis for World Polity and Civil Society theories on methane emissions in Table 6. For methane gas emissions, I confirm hypothesis H_3, and fail to confirm hypothesis H_{3a}.

Table 6. Results for Ordinary Least Squares Regression to investigate World Polity and Civil Society theories of methane emissions.

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	0.902*** (0.043)	0.903	0.937*** (0.049)	0.942
GDP per capita (logged)	0.193*** (0.043)	0.043	0.236*** (0.052)	0.249
Polity IV	-0.015 (0.004)	-0.150	-0.013** (0.005)	-0.131
INGOs			-0.003 (0.002)	-0.086
Constant	-2.866*** (0.373)		-3.130*** (0.418)	
Mean VIF	1.111		1.497	
Highest VIF	1.169		1.773	
R^2	.789		.792	
N	125		122	

Notes: * $p<.05$, ** $p<0.01$, *** $p<.001$ (two-tailed test); standard errors reported in parentheses.

Across both models in Table 6, I find the coefficients for the population and affluence control variables to be positive and statistically significant ($p<.01$). I also find across models the coefficient for the Polity IV democracy index remains negative, indicating an inverse relationship between level of democracy and methane gas emissions, but the statistical significance varies among models. In Model 1, only population and affluence are statistically significant predictors ($p<.001$) with an R^2 of .789, similar to the structural human ecology baseline model.

Model 2 includes international non-governmental organization presence among the predictors, and with its inclusion I find the effect of democracy to strengthen enough to meet the burden of statistical significance ($P<.01$), indicating the relative strength of a democracy alone is not sufficient to decrease methane gas emissions, but with the added civil societal engagement of international non-governmental organizations democracy grows in its inverse relationship to methane emissions. Model 2's R^2 increases to .792, indicating a better model fit for explaining the variance in methane emissions. The mean variance inflation factor remains relatively low at 1.497 in Model 2.

Methane Discussion

Across these analyses we see variables which increase methane gas emissions, population, affluence, and world-system position, and a factor which reduces methane emissions, level of democracy when controlling for international non-governmental organizational presence. Of the theoretical approaches to methane emissions, the structural human ecology perspective and the world polity perspective lend the most predictive power for the variance in methane gas emissions. This diverges from my findings for carbon dioxide gas emissions, where structural human ecology and ecologically unequal exchange provided the strongest explanations for the variance in carbon dioxide emissions. A fully saturated model including all of the theoretical models for methane is presented in Table 28 in the appendix.

The structural drivers for emissions differ among even the naturally occurring greenhouse gases, and indicate that policy to reduce greenhouse gas emissions must take into account the differential drivers which will in turn reduce emissions. For methane gas emissions, like carbon dioxide emissions, population and affluence remain as strong components which impact emissions, but also important is the role of civil society in mitigating methane emissions. I find that higher levels of democracy has an inverse relationship to methane emissions when controlling for the presence of international non-governmental organizations. Explaining less of the variance in methane gas emissions, but still significant enough to bear discussion is the impact of distance from the core in a world-system framework in driving methane gas emissions.

Nitrous Oxide Outcomes

Table 7 presents the results of the structural human ecology approach to nitrous oxide emissions.

Table 7. Results for Ordinary Least Squares Regression to investigate Structural human ecology theories of nitrous oxides emissions.

Model 4	
b	β
0.0005 (0.002)	-0.046
-0.011 (0.006)	0.148
0.963*** (0.056)	0.886
0.151 (0.082)	0.080
-0.021 (0.069)	0.0003
-2.992 (0.553)	
2.170	
3.793	
.804	
131	
Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed	

	Model 1		Model 2		Model 3	
	b	β	*b*	β	*b*	β
Urban Population			0.001 (0.002)	-0.051		
Non-Dependent Population			-0.010 (0.005)	0.155		
Population (logged)	0.964*** (0.044)	0.913	0.960*** (0.043)	0.914	0.979*** (0.056)	0.928
GDP per capita (logged)	0.139* (0.044)	0.089	0.140 (0.074)	0.086	0.094* (0.046)	0.089
(GDP per capita (logged))^2					0.016 (0.064)	0.010
Constant	-3.457*** (0.388)		-2.979*** (0.457)		-3.566*** (0.464)	
Mean VIF	1.080		2.096		1.092	
	1.080		3.137		1.154	
R^2	. 798		.792		.928	
N	131		131		131	

Model 1in Table 7 contains the greatest predictive model with the fewest variables, with an R^2 of .798 and a low mean variance inflation factor of 1.080. Total population shows a strong, positive, linear, statistically significant ($p<.001$) relationship to nitrous oxide emissions. Affluence, measured as gross domestic product per capita also exhibits a positive, linear relationship to nitrous oxide emissions, though meets the lower threshold of statistical significance ($p<.05$).

Model 2 in Table 7 investigates the effects of urbanization and the age dependency ratio. When controlling for population and affluence, neither urbanization nor non-dependent population attain statistical significance in affecting nitrous oxide emissions. The only variable which continues to exhibit a statistically significant effect on nitrous oxide emissions ($p<.001$) is total population when controlling for affluence, urbanization, and non-dependent population. Model 2 is a poor model, with a decreased R^2 from Model 1 of .792, and an elevated mean variance inflation factor of 2.096.

Model 3 tests for the potential curvilinear nature of affluence on nitrous oxide emissions. The quadratic transformation for gross domestic product per capita does not attain statistical significance. Total population, when controlling for affluence and the potential for a nonlinear relationship maintains statistical significance ($p<.001$). Affluence does achieve statistical significance, but at a more modest level when controlling for the other variables ($p<.05$). The R^2 increased in Model 3 to .798, and the variance inflation factor fell from Model 2 down to 1.409, indicating a better model overall compared to Model 2.

I present the fully saturated Structural human ecology model for nitrous oxide in Model 4 in Table 7. The results from Model 4 confirm hypothesis H_1, and fails to confirm hypotheses H_{1a}, H_{1b}, H_{1c}, H_{1d}. Model 4 has the highest collinearity of the structural human ecology nitrous oxide models with a mean variance inflation factor of 2.170. Controlling for all of the structural human ecology variables, only total population remains statistically significant ($p<.001$) in its positive linear relationship to nitrous oxide emissions. The R^2 increases in Model 4 to .804, and an additional variable, gross domestic product per capita approaches significance with a p value of .068.

The results investigating ecologically unequal exchange and nitrous oxide gas emissions are presented in Table 8. I fail to confirm hypotheses H_2, H_{2a}, or H_{2b} for nitrous oxide gas emissions.

Table 8. Results for Ordinary Least Squares Regression to investigate Ecologically Unequal Exchange theories of nitrous oxide emissions.

	Model 1		Model 2		Model 3	
	b	β	*b*	β	*b*	β
Population (logged)	0.971*** (0.045)	0.912	0.972*** (0.044)	0.914	0.992*** (0.064)	0.948
GDP per capita (logged)	0.061 (0.045)	0.057	0.006 (0.074)	0.006	0.125 (0.074)	0.122
Exports to High Income Countries	0.002 (0.002)	0.062	0.003 (0.002)	0.083	-0.00004 (0.002)	-0.001
Exports to High Income Countries X Low Income Countries			-0.002 (0.001)	-0.062		
WSP 2					0.081 (0.149)	0.041
WSP 3					-0.038 (0.153)	-0.017
WSP 5					-0.204 (0.182)	-0.080
WSP 6				-	0.116 (0.191)	0.059

Table 8. Continued.

	Model 1		Model 2		Model 3	
	b	β	*b*	β	*b*	β
WSP 7					-0.329 (0.184)	-0.129
WSP 8					0.029 (0.171)	0.017
WSP 9					0.123 (0.200)	0.060
WSP 10					-0.098 (0.214)	-0.459
Constant	-3.526*** (0.398)		-3.354*** (0.427)		-3.778*** (0.749)	
Mean VIF	1.299		2.000		3.913	
Highest VIF	1.456		3.031		6.674	
R^2	.805		.806		.846	
N	127		127		113	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

Across all models in Table 8, only population maintains a statistically significant coefficient. In Model 1, I find that population is positive and statistically significant (p<.001) for nitrous oxide gas emissions. In this model gross domestic product per capita and exports to high income countries are not statistically significant. These results are essentially repeated in Model 2, when I include the interaction variable for exports to high income countries from low income countries, and again in Model 3 when I include block positions from a world-systems framework. The independent variables for ecologically unequal exchange do not significantly predict variance in nitrous oxide emissions, only the structural human ecology control variable of population is remarkable in Table 8 for its persistence as a significant factor for emissions.

In Table 9, I present the findings for World Polity and Civil Society theories of nitrous oxide emissions. I fail to confirm hypotheses H_3 and H_{3a}.

Table 9. Results for Ordinary Least Squares Regression to investigate World Polity and Civil Society theories of nitrous oxide emissions.

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	0.953*** (0.044)	0.903	0.954*** (0.051)	0.903
GDP per capita (logged)	0.072 (0.043)	0.044	0.072 (0.054)	0.071
Polity IV	0.010* (0.005)	0.099	0.011* (0.005)	0.100
INGOs			0.00002 (0.002)	0.001
Constant	-3.332*** (0.385)		-3.340*** (0.434)	
Mean VIF	1.111		1.497	
Highest VIF	1.169		1.773	
R^2	.799		.801	
N	125		122	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

In Table 9, Model 1, I find that population has a positive, statistically significant coefficient (p<.001) which aligns to the findings in Table 7. In Model 1, the level of democracy is a statistically significant (P<.05) predictor for nitrous oxide emissions, but the effects move in the opposite direction theorized by world polity theory, where increased democracy is associated with increased nitrous oxide emissions. This impact persists in Model 2 when the presence of international non-governmental organizations is included in the analysis. The R^2 remains relatively stable across both models, .799 and .801, indicating the consistent importance of population and democracy to nitrous oxide emissions.

Nitrous Oxide Discussion

My investigation of nitrous oxide gas emissions reveals the different character of nitrous oxides as compared to the other naturally occurring greenhouse gases. A fully saturated model including all of the theoretical models for nitrous oxide is presented in Table 28 in the appendix. Similar to carbon dioxide and methane gas emissions, population is an important predictor for increases in nitrous oxide gas emissions, but further analyses fail to uncover equally strong factors which affect nitrous oxide gas emissions. The different quality of nitrous oxide gas emissions is in large part due to the balance of nitrous oxides from anthropogenic sources vs. naturally occurring sources. What makes nitrous oxide unique among the naturally occurring greenhouse gases is the larger share of its total emissions that are from natural sources. According to the IPCC, 62% of total nitrous oxide emissions come from the natural nitrogen cycle (Myhre et al. 2013). This investigation of the remaining 38% of nitrous oxide emissions may seem at its face somewhat unsuccessful, but taking into account the greater balance of total emissions from terrestrial sources, even the modest finding of population as the primary driver has the potential to inform public policy toward nitrous oxide emissions.

Chapter 5: Halogenated Species

Hydrofluorocarbon Outcomes

The results for the Structural human ecology models to explain hydrofluorocarbon emissions are presented in Table 10. I confirm hypotheses H_1 and H_{1a}. I fail to confirm hypotheses H_{1b} and H_{1c} when controlling for all structural human ecology variables.

Table 10. Results for Ordinary Least Squares Regression to investigate Structural human ecology theories of hydrofluorocarbon emissions.

	Model 1		Model 2		Model 3		Model 4	
	b	β	*b*	β	*b*	β	*b*	β
			-0.004 (0.005)	-0.067			-0.004 (0.005)	-0.074
			0.052*** (0.011)	0.275			0.047*** (0.012)	0.251
	0.937*** (0.087)	0.665	0.962*** (0.078)	0.683	0.807*** (0.104)	0.573	0.867*** (0.097)	0.616
	1.085*** (0.101)	0.661	0.976*** (0.146)	0.595	1.166*** (0.115)	0.710	1.016*** (0.188)	0.619
					-0.243 (0.145)	-0.112	-0.065 (0.153)	-0.031
	-8.047*** (0.796)		-10.967*** (0.956)		-7.428*** (0.892)		-10.156*** (1.070)	
	1.044		1.864		1.490		2.303	
	1.044		2.441		1.583		4.517	
	.700		. .762		.723		.770	
	86		86		86		86	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

		Urban Population	Non-Dependent Population	Population (logged)	GDP per capita (logged)	(GDP per capita (logged))^2	Constant	Mean VIF		R^2	N	

Model 1 in Table 10 provides the basic structural human ecology model, and explains approximately 70% of the variance in hydrofluorocarbon emissions. Model 1 provides a good fit for hydrofluorocarbon emissions where the coefficients both population and gross domestic product per capita are positive and statistically significant ($p<.001$). With so few predictors included in Model 1, the problems of collinearity often associated with international comparative research are greatly reduced compared to more heavily specified models, with a mean variance inflation factor of 1.044.

Model 2 in Table 10 investigates population in a more detailed fashion to untangle the effects of urbanization and the age structure as they affect hydrofluorocarbon emissions. Even while controlling for both of these additional factors, population and affluence remain positive and statistically significant ($p<.001$) and the R^2 increases to .762. Urbanization fails to meet the burden of significance, and has a negative coefficient, indicating that the theorized relationship between urbanization and hydrofluorocarbon emissions is not confirmed by this analysis. The percent of the population which is defined as non-dependent however, does exhibit a positive relationship to hydrofluorocarbon emissions and is statistically significant ($p<.001$) even while controlling for total population and affluence. Collinearity increases some in Model 2 over Model 1, with a mean variance inflation factor increasing to 2.441.

I investigate the theorized curvilinear relationship between affluence on hydrofluorocarbon emissions, but find no compelling evidence for a nonlinear relationship in Model 3. Instead, Model 3 indicates that population total is positive and statistically significant ($p<.001$). The R^2 falls from Model 2 to .723.

Finally, in Model 4 I present the fully saturated structural human ecology model, in which I confirm hypotheses H_1, H_{1a}, and H_{1c}. Even while controlling for all of the structural human ecology variables I find that population, gross domestic product per capita, and non-dependent population all exhibit a positive, statistically significant ($p<.001$) effect on hydrofluorocarbon emissions. Model 4 also has the highest R^2 of all of the structural human ecology models of .77. The factors most important among structural human ecology models for hydrofluorocarbon emissions are population, the age structure, and affluence.

Table 11 includes the results for Ordinary Least Squares analysis of ecologically unequal exchange theories for hydrofluorocarbon emissions. I fail to confirm hypotheses H_2, H_{2a}, and H_{2b} and find that population and affluence are the strongest statistically significant ($p<.001$) predictors for the variance in hydrofluorocarbon gas emissions across all models.

Table 11. Results for Ordinary Least Squares Regression to investigate Ecologically Unequal Exchange theories of hydrofluorocarbon emissions.

Model 3	
b	β
1.073*** (0.140)	0.743
1.002*** (0.205)	0.625
0.005 (0.004)	0.087
-0.148 (0.258)	-0.059
-0.052 (0.268)	-0.016
0.020 (0.359)	0.004
0.364 (0.400)	0.146

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	0.936*** (0.087)	0.665	0.942*** (0.085)	0.669
GDP per capita (logged)	1.023 *** (0.123)	0.623	0.841*** (0.156)	0.513
Exports to High Income Countries	0.004 (0.004)	0.066	0.005 (0.004)	0.086
Exports to High Income Countries X Low Income Countries			-0.007 (0.004)	-0.149
WSP 2				
WSP 3				
WSP 5				
WSP 6				-

Table 11. Continued.

Model 1	Model 2		Model 3	
β	*b*	β	*b*	β
			0.187 (0.428)	0.036
			-0.112 (0.333)	-0.040
			-0.768 (0.447)	-0.220
			0.590 (0.542)	0.094
	-7.395*** (0.863)		-9.060*** (1.802)	
1.031	1.753		4.078	
1.368	2.571		9.223	
.702	.714		.826	
86	86		74	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

	b
WSP 7	
WSP 8	
WSP 9	
WSP 10	
Constant	-8.055*** (0.797)
Mean VIF	
Highest VIF	
R^2	
N	

No other variables are statistically significant (p<.05) across the models for ecologically unequal exchange. The R^2 ranges from .702 to .826 across models, and collinearity grows as a concern across models, where the variance inflation factor increases from 1.031 in Model 1 to 4.078 in Model 3, due in most part to the structure of the world-system position dummy variables.

In Table 12 I present the results for World Polity and Civil Society theories for hydrofluorocarbon gas emissions.

Table 12. Results for Ordinary Least Squares Regression to investigate World Polity and Civil Society theories of hydrofluorocarbon emissions.

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	0.987*** (0.094)	0.640	1.174*** (0.100)	0.766
GDP per capita (logged)	0.987*** (0.094)	0.094	1.378*** (0.129)	0.835
Polity IV	0.002 (0.011)	-0.150	0.008 (0.010)	0.050
INGOs			-0.014** (0.004)	-0.271
Constant	-8.454*** (0.373)		-10.277*** (0.907)	
Mean VIF	1.157		1.766	
Highest VIF	1.235		2.302	
R^2	.717		.778	
N	82		79	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

Model 1 presents the findings for hypothesis H_3, which I fail to confirm. When controlling for population and affluence, level of democracy does not have a statistically significant effect on hydrofluorocarbon emissions. The R^2 for Model 1 is .717 in large part due to the statistically significant ($p<.001$) effects of population and gross domestic product per capita.

Model 2 in Table 12 includes an additional civil society variable, international non-governmental organization presence, which has an inverse relationship to hydrofluorocarbon emissions. In Model 2 I confirm hypothesis H_{3a}. The R^2 increases in Model 2 to .778, where population, affluence, and strong civil society all affect hydrofluorocarbon emissions.

Hydrofluorocarbon Discussion

Hydrofluorocarbon gas emissions are the first of the class of emissions known as the halogenated species, and represent the most understudied and least well understood from a structural ecological standpoint. This lack of good comparative analysis of the halogenated species is paradoxical because this class of emissions is entirely anthropogenic. There are no natural sources for these emissions, they arise entirely from human activity and by this fact are arguably the best to investigate for social determinants. Hydrofluorocarbon gas emissions follow similar structural pathways as the naturally occurring greenhouse gas emissions, which is to say that population and affluence are the primary factors which account for the variance in hydrofluorocarbon emissions cross-nationally when accounting for a range of structural explanations for emissions. The structural human ecology framework represents a good fit for understanding what increases hydrofluorocarbon emissions, where total population and gross domestic product per capita alone account for 70% of the variance in hydrofluorocarbon gas emissions. A fully saturated model including all of the theoretical models for hydrofluorocarbon gas is presented in Table 29 in the appendix.

Ecologically unequal exchange did not result in significant support for the differential emissions across the world based on trade between less affluent and high income countries, or world-system position. This result is not entirely baffling if we take into consideration the primary sources for hydrofluorocarbon gas emissions and their consumption in more affluent nations. Hydrofluorocarbon gases come primarily from their use as a substitute for ozone depleting substances once used in refrigerants. (Myhre et al. 2013). The use of refrigerants and widespread access to electricity are luxuries afforded to the wealthiest nations, and so the findings indicating that indicate distance from the core does not significantly affect the variance in hydrofluorocarbon gas emissions is understandable, and not incompatible with ecologically unequal exchange theory.

Civil society may prove to be an avenue of potential to reduce hydrofluorinated gas emissions. When controlling for democracy and the structural human ecology variables, I find that international non-governmental organization presence in terms of the number of organizations present in a given nation, has a dampening effect on hydrofluorocarbon emissions. The role of civil society as a mitigating influence on greenhouse gas emissions is a promising avenue for climate change harms reduction and adaptation policy. This result supports the potential for civil society to act at the structural level to reduce emissions.

Perfluorinated Outcomes

Table 13 provides the Ordinary Least Squares analysis of structural human ecology theories for perfluorinated emissions. Across all models presented, population displays the most consistent and statistically significant ($p<.001$) relationship to perfluorinated gas emissions, thereby confirming hypothesis H_1.

Table 13. Results for Ordinary Least Squares Regression to investigate Structural human ecology theories of perfluorinated emissions.

	Model 1		Model 2		Model 3		Model 4	
	b	β	*b*	β	*b*	β	*b*	β
			0.001 (0.008)	-0.067			0.005 (0.008)	0.097
			0.028 (0.018)	0.275			0.060** (0.021)	0.342
	0.866*** (0.129)	0.665	0.880*** (0.130)	0.683	0.882*** (0.176)	0.717	0.997*** (0.174)	0.810
	0.332 (0.166)	0.661	0.238 (0.251)	0.595	0.157 (0.214)	0.099	-0.396 (0.331)	-0.250
					0.320 (0.246)	0.172	0.793** (0.286)	0.427
	-5.394*** (1.337)		-7.028*** (1.762)		-4.974** (1.558)		-8.198*** (1.953)	
	1.147		1.822		1.490		2.726	
	1.147		2.621		1.583		5.034	
	.434		.455		.723		.522	
	62		62		62		62	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

		Urban Population	Non-Dependent Population	Population (logged)	GDP per capita (logged)	(GDP per capita (logged))^2	Constant	Mean VIF		R^2	N	

I also find, when controlling for all structural human ecology variables, that the percent of the population which is non-dependent exerts a positive and statistically significant ($p<.01$) effect on perfluorinated gas emissions, confirming hypothesis H_{1c}. I fail to confirm hypothesis H_{1a}, H_{1b}, and H_{1d}. Model 1 includes only the population and affluence variables, and has an R^2 of .434. Population alone in Model 1 is statistically significant, but the model explains less than half of the variance in perfluorinated gas emissions.

Model 2 in Table 13 investigates the potential for urbanization and the age structure for effects on perfluorinated gas emissions. The results indicate that while controlling for population and affluence, neither urbanization, nor non-dependent population exert a statistically significant ($p<.05$) effect on perfluorinated gas emissions. The R^2 only increases slightly from Model 1 to .455, and the mean variance inflation factor to assess collinearity rises to 2.621.

I investigate the potential nonlinear relationship between population and perfluorinated gas emissions, and affluence and perfluorinated gas emissions in Model 3. The R^2 falls in Model 3 to .450, and although the coefficient for population is positive, and the coefficient for the quadratic transformation of population is negative, only the population variable achieves statistical significance ($p<.001$). The opposite signs of the population variable and the quadratic transformation of the population variable does indicate that there may be a nonlinear effect between population growth over time and perfluorinated gas emissions, I cannot rule out the possibility that the opposite directions of the coefficients was merely by chance.

Finally, Model 4 of Table 13 provides the fully saturated structural human ecology model, including all of the structural human ecology variables I find that population, non-dependent population, and the quadratic transformation of gross domestic product per capita all attain statistical significance. Interpretation of the population variables is fairly straightforward, where population and non-dependent population exhibit positive, linear relationships to perfluorinated gas emissions when controlling for all independent structural human ecology variables. Less straightforwardly interpreted, the quadratic transformed affluence variable seems to indicate that perfluorinated gas emissions increase in intensity at the highest levels of affluence among nations. Model 4 has the highest R^2 value of Table 13 at .522, but also has the highest collinearity among models, although not high enough to deem the results unacceptable with a mean variance inflation factor of 2.726.

The results for Ordinary Least Squares regression analysis for perfluorinated emissions from an ecologically unequal exchange perspective are presented in Table 14.

Table 14. Results for Ordinary Least Squares Regression to investigate Ecologically Unequal Exchange theories of perfluorinated emissions.

Model 3	
b	β
1.159*** (0.237)	1.010
0.911** (0.302)	0.637
-0.006 (0.007)	-0.137
0.233 (0.354)	0.124
0.502 (0.369)	0.219
1.093+ (0.613)	0.371
0.795 (0.583)	0.331

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	0.843*** (0.028)	0.685	0.851*** (0.124)	0.691
GDP per capita (logged)	0.843** (0.169)	0.338	0.490* (0.220)	0.309
Exports to High Income Countries	-0.015** (0.005)	-0.311	-0.015** (0.005)	-0.306
Exports to High Income Countries X Low Income Countries			-0.002 (0.006)	-0.042
WSP 2				
WSP 3				
WSP 5				
WSP 6				-

Table 14. Continued.

Model 1	Model 2		Model 3	
β	*b*	β	*b*	β
			0.652 (0.643)	0.144
			-0.374 (0.490)	-0.115
			1.709+ (0.946)	0.271
			2.161+ (1.112)	0.342
	-4.858** (1.328		-9.903** (3.129)	
1.249	1.664		3.808	
1.358	2.251		6.624	
.512	.513		.645	
62	62		52	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

	b
WSP 7	
WSP 8	
WSP 9	
WSP 10	
Constant	-4.986*** (1.259)
Mean VIF	
Highest VIF	
R^2	
N	

In Model 1 I find the structural human ecology control variables are both positive and statistically significant (P<.01) indicating they exert a positive effect on perfluorinated gas emissions. Also included in Model 1 is exports to high income countries variable, which is inversely related to perfluorinated gas emissions. The direction of the coefficient for the exports to high income countries variable is opposite of what was predicted, and therefore I fail to confirm hypothesis H_2. The sample size is greatly reduced for the perfluorinated gas analysis due to data availability. The baseline model R^2 is lower than in prior analyses conducted in this research study of only .512.

Model 2 in Table 14 includes the interaction variable for exports to high income countries from low income countries. Population and gross domestic product remain positive and statistically significant (p<.05) in Model 2, and the exports to high income countries variable remains negative and statistically significant (p<.01). The interaction variable fails to gain statistical significance, further compelling the need to include world-system position as an alternative measure for the effect of ecologically unequal exchange on perfluorinated gas emissions. With this result, I fail to confirm hypothesis H_{2a}. The R^2 for Model 2 only increases nominally to .513.

Model 3 includes a series of dummy variables for world-system position, and although none of the coefficients meets the strictest levels of significance, three positions approach statistical significance ($p<.10$) including world-system position 5, position 9, and position 10. These three coefficients are each positive and may indicate increased perfluorinated gas emissions in areas more distant from the core nations in a world-system framework. This finding lends weak support to hypothesis H_{2b}, but I fail to confirm this hypothesis resoundingly. The exports to high income countries variable loses statistical significance in Model 3, lending additional clarity to the interpretation for what seemed like an inverse relationship in Models 1 and 2, instead, I argue that the interpretation of the coefficient for exports to high income countries cannot be understood without controlling for world-system position, and even then, the results are not statistically significant, indicating the relationship between exports to high income countries is not uniformly distributed among less affluent nations, and would require detailed case studies for better understanding. The R^2 for Model 3 improves to .645, and the mean variance inflation factor is 3.808 due to the closely linked world-system variables.

Table 15 contains the analyses for world polity and civil society theory on perfluorinated gas emissions. Consistent with the research thus far, the structural human ecology variables of population and gross domestic product per capita are positive and statistically significant ($p<.01$) in Model 1.

Table 15. Results for Ordinary Least Squares Regression to investigate World Polity and Civil Society theories of perfluorinated emissions.

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	1.000 *** (0.130)	0.767	1.007 *** (0.149)	0.794
GDP per capita (logged)	0.551** (0.180)	0.341	0.570** (0.214)	0.249
Polity IV	-0.039*	-0.253	-0.039*	-0.131

	(0.016)		(0.017)	
INGOs			-0. 0005 (0.006)	-0.010
Aid to INGOs (logged)				
Constant	-7.050*** (1.367)		-7.133*** (1.538)	
Mean VIF	1.304		1.708	
Highest VIF	1.463		1.673	
R^2	.522		.540	
N	60		57	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

The effect of the level of democracy is as hypothesized by world polity theory, where democracy is statistically significant coefficient ($p<.05$) and has an inverse relationship with perfluorinated gas emissions, therefore I confirm hypothesis H_3. The R^2 for model 1 is modest, at .522, and the sample size is affected by data availability.

Model 2 enhances the world polity and civil society theory with the addition of the international non-governmental organization presence variable. Although the variable does not meet the threshold of significance when controlling for structural human ecology variables and democracy, the coefficient is negative, indicating a possibly inverse relationship as predicted by theory. Despite the possible direction of the theorized relationship, I fail to confirm hypothesis H_{3a}. The R^2 increases some between Model 1 and 2, to .540. Model 2 lends further support to the role of democracy in reducing perfluorinated gas emissions, but fails to confirm the role of international non-governmental organizations' role in perfluorinated gas reduction.

Perfluorinated Discussion

The analyses of perfluorinated gas emissions through the lenses of large scale, macro level structural social theory, like hydrofluorocarbon gas emissions, and the naturally occurring greenhouse gases are heavily influenced in a positive and linear fashion by the structural human ecology variables of population and affluence. These two variables alone account for 43% of the variance in perfluorinated gas emissions. This finding is less pronounced than the other greenhouse gases analyzed thus far, but still contributes a considerable amount to our understanding of the pathways which drive perfluorinated gas emissions. Like hydrofluorocarbon gas emissions and sulphur hexafluoride, these halogenated species are not naturally occurring, and emissions are generated solely by anthropogenic activity. The primary source for perfluorinated gases is the byproduct of the production and transmission of electricity, a benefit not equally distributed internationally (Myhre et al. 2013). A fully saturated model including all of the theoretical models for perfluorinated gas is presented in Table 29 in the appendix.

Ecologically unequal exchange provides an avenue to better understand the nuanced effects that a nation’s position in trade, and in the world-system plays in attenuating the effects of trade on perfluorinated gas emissions. In this analysis I find that the inclusion of world-system position enhances the ability to understand the effect of trade, specifically exports of manufactured goods to high income countries. In general, those countries with greater distance from the core may exhibit higher perfluorinated gas emissions when controlling for exports to high income countries. The ecologically unequal exchange model accounts for the greatest percent of the variance in perfluorinated gas emissions across all models and theories, though this number is still moderately low as compared to the results for better studied outcomes such as carbon dioxide emissions, where data are more readily available.

The role of civil society in reducing perfluorinated gas emissions may afford the pathway to policy which reduces perfluorinated gas emissions. Increased democracy is associated with decreased perfluorinated gas emissions. Although international non-governmental organization presence does not rise to the level of statistical significance, the coefficient for this variable is negative, indicating the potential for an inverse relationship as data availability grows and cases for which data are missing are decreased over time with better collection and reporting. This series of analyses on perfluorinated gas emissions indicates that population and affluence increase emissions, but civil society through democratic structures has the potential to decrease emissions.

Sulphur Hexafluoride Outcomes

The results of Ordinary Least Squares Regression Analysis for structural human ecology theories and Sulphur hexafluoride gas emissions are presented in Table 16. When controlling for all variables I confirm hypothesis H_1, and fail to confirm H_{1a}, H_{1b}, H_{1c}, H_{1d}.

Table 16. Results for Ordinary Least Squares Regression to investigate Structural human ecology theories of sulphur hexafluoride emissions.

Model 4	
b	β
0.013 (0.007)	0.097
0.043 (0.018)	0.342
1.434*** (0.181)	0.810
-0.127 (0.386)	-0.250
0.617 (0.344)	0.427
-11.665*** (2.006)	
3.577	
7.725	
. 704	
58	
Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed	

	Model 1		Model 2		Model 3	
	b	β	*b*	β	*b*	β
Urban Population			-0.002 (0.002)	-0.051		
Non-Dependent Population			0.015** (0.005)	0.155		
Population (logged)	1.380*** (0.140)	0.704	0.909*** (0.042)	0.914	1.380*** (0.190)	0.970
GDP per capita (logged)	0.697*** (0.179)	0.209	0.086 (0.072)	0.086	0.605 (0.305)	0.332
(GDP per capita (logged))^2					0.121 (0.319)	0.057
Constant	-10.533*** (1.580)		-3.497*** (0.444)		-10.221*** (1.903)	
Mean VIF	1.522		1.764		3.277	
	1.522		2.395		4.312	
R^2	.652		.685		.653	
N	58		58		58	

Model 1 in Table 16 has an R^2 of .652, and both population and gross domestic product per capita are statistically significant and positively correlated with sulphur hexafluoride emissions.

I investigate population effects in Model 2 of Table 16 for sulphur dioxide emissions and find that when controlling for population and affluence, non-dependent population has a statistically significant ($p<.01$) positive relationship to sulphur hexafluoride emissions. The coefficient for population in Model 2 is also positive and statistically significant ($p<.001$), and the R^2 increases in Model 2 to .685 indicating slightly better explanation of the variance in sulphur hexafluoride gas emissions over Model 1.

Model 3 includes quadratic transformations for both population and gross domestic product per capita to investigate the theorized curvilinear relationship between population and affluence on sulphur hexafluoride gas emissions. I find that population may exhibit a curvilinear relationship to sulphur hexafluoride emissions, as the coefficient for population is positive, while the quadratic transformation of population is negative, however I cannot rule out the possibility that this sign change is merely by chance as the coefficient for the quadratic transformation of population fails to meet the threshold of significance. Otherwise, population is positive and statistically significant ($p<.001$), but the overall R^2 declines in Model 3, while collinearity increases and the mean variance inflation factor rises to 3.277.

The fully saturated model for structural human ecology theory is presented in Model 4 in Table 16 and provides the largest explanation for the variance in sulphur hexafluoride emissions with an R^2 of .704. When controlling for all of the structural human ecology independent variables, only population maintains a statistically significant ($p<.001$) relationship to sulphur hexafluoride emissions. Collinearity, like most of the cross national models for greenhouse gas emissions is a chief concern, and here in Model 4 of Table 16 I find the largest variance inflation factors for structural human ecology models with a mean VIF of 3.577. This score, while acceptable, is less desirable than a lower mean.

The results investigating ecologically unequal exchange and sulphur hexafluoride are presented in Table 17, and provide evidence to confirm hypothesis H_{2b}, but I fail to confirm hypotheses H_2 and H_{2a}.

Table 17. Results for Ordinary Least Squares Regression to investigate Ecologically Unequal Exchange theories of sulphur hexafluoride emissions.

	Model 1		Model 2		Model 3	
	b	β	*b*	β	*b*	β
Population (logged)	1.326*** (0.130)	0.932	1.322*** (0.131)	0.691	1.288*** (0.155)	1.044
GDP per capita (logged)	0.826*** (0.169)	0.453	0.891*** (0.212)	0.309	0.689*** (0.187)	0.457
Exports to High Income Countries	-0.016** (0.005)	-0.260	-0.016** (0.005)	-0.306	-0.005 (0.005)	-0.088
Exports to High Income Countries X Low Income Countries			0.002 (0.005)	-0.042		
WSP 2					0.131 (0.223)	0.071
WSP 3					0.360 (0.242)	0.182
WSP 5					0.908** (0.334)	0.290
WSP 6				-	0.100 (0.400)	0.028

Table 17. Continued.

Model 3
β
0.164
-0.077
0.182
0.007
2.972
4.059
.847
51
Notes: * p<.05, ** p

	Model 1		Model 2		
	b	β	*b*	β	*b*
WSP 7					0.711+ (0.406)
WSP 8					-0.189 (0.289)
WSP 9					1.103* (0.479)
WSP 10					0.043 (0.494)
Constant	-9.542*** (1.487)		-9.774*** (1.563)		-9.632*** (1.981)
Mean VIF	1.440		1.783		
Highest VIF	1.608		2.494		
R^2	.710		.712		
N	58		58		

Across all models, the coefficients for the control variables population and gross domestic product per capita are positive and statistically significant ($p<.001$). Model 1 indicates that without controlling for position in the world-system, or position as a trading partner, that exports to high income countries are statistically significant ($p<.01$) and negatively related to sulphur hexafluoride emissions. This runs counter to prevailing arguments for ecologically unequal exchange and greenhouse gas emissions, most specifically, carbon dioxide. The R^2 for Model 1 is .71.

Model 2 specifies the model more specifically with an interaction variable for exports to high income countries from low income countries, the coefficient for which is not statistically significant, but is a positive number, indicating that the effects of trade from less affluent countries is different in character from those more affluent countries when it comes to the export of manufactured goods. The R^2 increases very slightly to .712, and the exports to high income countries variable maintains statistical significance (p<.01).

In Model 3, world-system block positions are included to disaggregate the effects of position in the world-system on sulphur hexafluoride emissions. I find that when controlling for world-system position, exports to high income countries loses statistical significance, while population and affluence maintain statistical significance (p<.001). Including world-system position makes clear the pathways through which trade, specifically exports to high income countries, may increase sulphur dioxide emissions. World-system position blocks 5 and 9 have positive, statistically significant coefficients (p<.01 and p<.05, respectively), and block 7 approaches significance (p<.10). Model 3 explains the greatest portion of the variance in sulphur dioxide gas emissions across all models at .847. Collinearity is an ongoing concern with cross-national research, but the mean variance inflation factor for Model 3 is 2.972, and within the acceptable range.

Table 18 provides the results for analyses of sulphur hexafluoride from a world polity perspective.

Table 18. Results for Ordinary Least Squares Regression to investigate World Polity and Civil Society theories of sulphur hexafluoride emissions.

	Model 1		Model 2	
	b	β	*b*	β
Population (logged)	1.473 *** (0.123)	0.995	1.488 *** (0.135)	1.016
GDP per capita (logged)	0.967*** (0.155)	0.543	1.003*** (0.178)	0.570
Polity IV	-0.064***	-0.392	-0.064***	-0.387

	(0.012)		(0.013)	
INGOs			-0.003 (0.002)	-0.049
Constant	-11.933*** (1.370)		-12.010*** (0.418)	
Mean VIF	1.418		1.602	
Highest VIF	1.640		2.089	
R^2	.758		.758	
N	56		54	

Notes: * p<.05, ** p <0.01, *** p<.001 (two-tailed test); standard errors reported in parentheses.

The results across both models in Table 18 are remarkably similar, population and gross domestic product have positive, statistically significant ($p<.001$) coefficients, and the level of democracy is statistically significant ($p<.001$) and has an inverse relationship with sulphur hexafluoride emissions. I confirm hypothesis H_3 and fail to confirm hypothesis H_{3a}. The R^2 remains unchanged between models at .758. Results indicate that when controlling for structural human ecology variables, increased democracy leads to decreased sulphur hexafluoride gas emissions.

Sulphur Hexafluoride Discussion

Sulphur hexafluoride gas emissions are not unlike the other halogenated species of greenhouse gas emissions, where the structural human ecology variables of population and affluence alone account for 65% of the variance in sulphur hexafluoride emissions. Indeed, across all analyses, these predictor variables remain powerful in affecting sulphur hexafluoride emissions. The model for which the greatest variance is explained comes through the ecologically unequal exchange analysis, where world-system position attenuates the otherwise inverse effect of exports to high income countries by nature of a nation's position in the world-system, and what that location reveals about a nation in terms of trade. A fully saturated model including all of the theoretical models for sulphur hexafluoride is presented in Table 29 in the appendix.

The emission of sulphur hexafluoride, like all of the halogenated species of greenhouse gas emissions, is an entirely man-made process and is primarily created as a byproduct of the manufacturing process in manufacturing semi-conductors and aluminum (Myhre et al. 2013). Due to the specialized manufacturing process associated with sulphur hexafluoride emissions, it is understandable that overall manufactured imports as a variable may not capture the specific effects of semi-conductor and aluminum specific manufacturing.

Finally, world polity theory provides a pathway to sulphur dioxide gas emissions, where increased democracy is associated with decreased emissions. The openness and transparency of democracies allows a pathway through which sulphur hexafluoride, and the halogenated species in particular, may be greatly reduced. The purely anthropogenic nature of the halogenated species provides a broader opportunity to reduce the emissions of the class of greenhouse gases which have much higher radiative forcing and global warming potential than their naturally occurring counterparts. Greenhouse gases created by human activity are ideally suited to be reduced by alternative human activity.

Chapter 6: Discussion and the Path Forward

Outcomes Summary

As I suspected, with the exception of population, and perhaps democracy to a lesser extent, the structural factors which drive greenhouse gas emissions vary depending upon the outcome greenhouse gas measured. Specifically, when I group the greenhouse gases into naturally occurring and the halogenated species I find differences emerge in the effects of the working age population and affluence. The non-dependent population variable increases hydrofluorocarbon and perfluorinated carbon gas emissions and gross domestic product per capita increases all of the halogenated species.

Table 19. Summary of Statistically Significant Theoretical Findings per Gas

	CO_2	CH_4	N_2O	HFC	PFC	SH_6
Structural Human Ecology	+	+	+	+	+	+
World-System Theory		+			+	
Ecologically Unequal Exchange						
World Polity Theory	-	-	+	-	-	-

Of all of the structural variables analyzed, population is the key predictor which exhibits a positive, linear relationship to each of the greenhouse gases. For every gas analyzed, total population exhibited a statistically significant and strong relationship to emission totals even while controlling for a wide variety of variables. The next most important factor is level of democracy, which exhibits an inverse relationship with four of the six greenhouse gases including carbon dioxide, methane, perfluorinated carbon, and sulphur hexafluoride. Affluence remains an important factor, which increases emissions in carbon dioxide, hydrofluorocarbon, perfluorinated carbon, and sulphur hexafluoride gas. The age dependency variable was identified as increasing methane, hydrofluorocarbon, and perfluorinated carbon gas emissions. Rounding out the remaining factors, world system position, specifically distance from the core increases methane and perfluorinated carbon gas emissions, and international non-governmental organization presence decreases emissions for carbon dioxide and hydrofluorocarbon emissions.

These results are not novel in the sense that they break ground unexpectedly, but they do contribute new knowledge regarding the social structural drivers for the halogenated species and nitrous oxide in particular. These greenhouse gases, understudied and unstudied in the sociological research will become critical in the coming years as the impacts of climate change become manifest. As efforts to reduce carbon dioxide emissions already part of the sustainability conversation do not fully incorporate the structural drivers for the purely anthropogenic halogenated species, greater attention must be paid to the halogenated species. With increased democracy, we may implement strategies to reduce emissions and improve the quality of life for billions around the world.

Implications for Future Research

For future research, interaction variables, such as those used to investigate the interactions between several of the structural level variables would do well to better specify the effects on greenhouse gas emissions. Additionally, further research would do well to include additional inequality variables such as within country inequality measured as the GINI coefficient, and gender variables to predict greenhouse gas emissions. The GINI coefficient has not been demonstrated to be statistically significantly related to carbon intensity, but may hold additional insight into the halogenated species. In studies which limit outcomes to a single greenhouse gas, or a group of greenhouse gases such as the naturally occurring or halogenated species, additional control variables would be beneficial. For this comparative project, additional control variables to be applied uniformly were not appropriate. For example, deforestation has a well-documented effect on carbon dioxide emissions, but is an inappropriate control variable for the halogenated species as they are not directly related to deforestation like carbon dioxide. Another example of a control variable useful for some greenhouse gas emissions, but not appropriate in a comparative study such as this would be a land use variable, which would prove beneficial in the naturally occurring species, but like deforestation, would not inform the study of the halogenated species. A land mass or land use change variable in future research could serve to better understand the naturally occurring species of greenhouse gas emissions in particular, and may serve to understand the changes which come from modernization.

Other considerations for future research include additional methodological possibilities, including alternative methods for addressing issues of collinearity inherent in national level studies. Principal components analysis could serve to triangulate findings for future researchers, as well as additional methods including structural equation modeling and two stage least squares to better specify the potential indirect effects of the national level independent variables on greenhouse gas emissions. Structural equation modelling in particular is an avenue through which additional research can decompose the direct and indirect effects of those social theories which predict greenhouse gas emissions in the vein of research conducted on deforestation, threatened mammal and bird species, gender interaction effects with carbon dioxide emissions, (Burns 1994, McKinney et al. 2010, McKinney and Fulkerson 2015.)

Policy Implications for Climate Change Mitigation

Two policy strategies to reduce greenhouse gas emissions only operate within the context of free, transparent democratic governance. The demonstrated effect of civil society on reducing greenhouse gas emissions provides the structural conditions which create the environment in which greenhouse gas emissions policy may be effective. These policies come from the climate justice literature, and encourage action within the economy, specifically market solutions shown to be effective with other ecological and social problems in the past, divestment and cap and trade. Divestment, which arguably is best suited as a strategy to employ in wealthy nations most responsible for climate change, like the United States, involves withdrawing financial support from publicly traded companies who themselves burn fossil fuels or increase greenhouse gas emissions through their everyday transactions. Cap and trade, when entered into fully and with proper accounting has the potential to incentivize ecologically sound practice in industry, and to encourage sustainable policy within companies who are greenhouse gas emitters. Both strategies are attempts to address the finite "carbon budget" or the absolute limit beyond which additional greenhouse gases cause irrevocable harm. From a climate justice perspective, failure to act to reduce emissions before reaching our budget will have far reaching consequences, not just in terms of the climate change impacts, but how we ethically move forward in a world essentially compromised by the few, but with negative consequences for all (McKinnon 2015).

Divestment as a movement strategy has its highest profile case which first made it popular as a tactic for changing the social order during South African Apartheid. Beginning in 1977, students from Stanford University began a divestment movement that soon spread to over 150 universities divesting interests from their foundations form South Africa during the anti-Apartheid campaign (Linnenluecke et al. 2015). Apartheid in South Africa was a segregated social system in which black South Africans, 72% of the total population of South Africa, were systematically and openly denied access in society and were forced to live as second class citizens, in fear of wrongful imprisonment and worse. The anti-Apartheid movement faced steep opposition among white South Africans, who stood to see higher taxes, less political power, and increased market competition (Schneider 2015). Despite the pressure to maintain economic interests in an openly racist nation known for exploitation of its black community, by 1989 25 states, 19 counties, and 83 cities in the United States passed binding legislations against firms conducting business in South Africa (Schneider 2015).

The current wave of the fossil fuel divestment movement began at Swarthmore College in 2011, where the top 200 fossil fuel companies with the largest reserves have been identified for divestment of stocks and investments (Linnenluecke et al. 2015; Stewart 2014). The goal of divestment is to promote climate justice, by voting with investment dollars, citizens and organizations in affluent nations have the ability to raise awareness of the impact of greenhouse gas emissions on climate change, while also promoting sustainable organizations rather than unsustainable, heavy emitters (Schneider 2015).

There is a divestment movement underway in Germany, and paired with the greenhouse gas emission cap legislation passed there, evidence indicates that the work of the divestment strategy and carbon cap policy has successfully called attention to the issue of climate justice and evidence indicates the largest German energy firms have begun to realign and start restructuring toward renewable energy (Kiyar and Wittneben 2015).

As a strategy, divestment and the climate justice movement has the rare opportunity to right the wrongs on not just economic injustice, but also to enhance justice through expanding the scope to include human rights, and promoting rights based risk management with corporations (Olawuyi 2016). Indeed, human rights and climate change mitigation efforts are naturally paired, so much so that the Paris Agreement includes this inextricable link between human rights and the rights to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities, vulnerable people, the right to development, gender equality, women's empowerment, and intergenerational equity as the third major statement of the Paris Agreement (United Nations 2015). Divestment from pollution intensive industry will allow for the enhanced development of clean development mechanisms, and deforestation and forest degradation projects which are linked to human rights and the remaining principles of the Paris Agreements recognizing the wealth of differences to be accounted for to improve the effects of the intersection of difference (Olawuyi 2016).

The work of unveiling the structural drivers of greenhouse gas emissions is an intellectual exercise, but in and of itself is not sufficient for social change without looking to those structural factors which serve to drive real world policy change. The predominant form global greenhouse gas emission reduction schemes in service to climate change mitigation have been cap and trade programs, and here I present the assumptions which underlie these policies. The dominant paradigm which informs both global economics which serve to promote ecologically unequal exchange, as well as efforts to implement cap and trade emissions reduction programs is neoliberal, and comes from a market environmentalism orientation. If we are to truly formulate effective policies to abate greenhouse gas emissions and mitigate climate change, then the theory that generates these programs must be fully understood if it is to be applied accurately. Despite the relatively conservative orientation in economics which generated the notion of cap and trade policy, in practice, and among supporting non-governmental organizations and environmentalists however, actual cap and trade programs do not strictly adhere to orthodox neoliberal thought.

At the heart of the current move within the international environmental community toward cap and trade policies to reduce greenhouse gas emissions is a fundamental outlook toward nature which seeks to monetize and place economic value on ecosystem services otherwise overlooked and not accounted for in traditional economics. This outlook is one that accounts for the costs and benefits of nature itself. Although much deep environmentalist thinking defies traditional economic conceptions of the interaction between the social and natural worlds, the need to incorporate environmental costs into traditional economics is necessary if we are to mitigate climate change short of nuclear winter. Traditional economic theory is concerned with increasing economic development, or income, through openness to trade, and developing a comparative advantage (Bhagwati 2007, Nafziger 2006). In this classical conception of economics and development, every country in a globalized network should focus on specialization, emphasizing a few diverse industries specialize in and to export goods or services. If each nation in the system has a few specializations for which they can produce goods or services at a cheaper, or more competitive rate, then there develops an international division of labor, in which every nation complements the other, or each has a well-developed comparative advantage (Bhagwati 2007, Nafziger 2006). This is the economic theory at the heart of development economics and the study of economics in general; of course there are many variations, some emphasize diversifying the sectors from which a country exports, others on reducing protectionist policies that limit full integration into a globalized market (Nafziger 2006). The common thread lies, however, in the belief that openness to trade, from the most developed to the least developed nations, is good for all involved.

The theory of unequal exchange arose, in part, as a critique of this notion of comparative advantage and instead of specialization attracting industry specific investment where each nation or group of nations enjoys the benefits of being the specialists, instead the asymmetry of power between wealthy nations and less developed nations contributes to the acceptance on the part of less developed nations of ecologically harmful business practices and abysmal working conditions for many in the contemporary textile trade (Mahutga 2014; Rice 2009; Wallerstein 2004).

Social scientists in the last several years have begun to address the effect of neoliberal thought on the environment. In particular, the growth in "neoliberalizing nature." Neoliberal environmental thought and policies are actually part of a larger theoretical movement within environmental policy development called "market environmentalism" (Anderson and Leal 2001, Bakker 2005, Bailey 2007, Mansfield 2004). Market environmentalism is a body of theory that draws specifically from economic thought, and in particular, neoliberal economic theory.

Inherent in "market environmentalism" is the belief that including the environment in these economic cost benefit analyses is the best way to save the environment. In other words, to price the services the healthy environment provides, and the accompanying loss of services provided with environmental harm is essential to this market understanding of addressing environmental concerns (Anderson and Leal 2001, Bakker 2005, Liverman 2004). Quantifying the environment in this way means that the services nature provides can be included in cost benefit analyses as a benefit, while environmental harms and hence reduction of nature's services are a cost. Another critical assumption of "market environmentalism," and one of the major philosophical tenets which supports cap and trade policies, is the belief in markets, with little, and ideal typically, no state interventions, are best capable of addressing environmental problems (Anderson and Leal 2001, Bailey 2007, Bakker 2005, Mansfield 2004).

Neoliberal environmental policy is not a mono-process, where all neoliberal environmental policy is identical, and always perfectly adheres to the theoretical assumptions which drive it (Mansfield 2004). Instead, real world neoliberal environmental policies fall somewhere between two extremes, one being a strict orthodox neoliberalism, characterized by total market control and absolutely no state intervention, and the other a more liberal, neoliberal policy, which also includes state controls and interventions coupled with market forces. Naturally, investigations into neoliberal environmental policy diverges at many points, not all environmental problems require the same solution, and certainly the scope of the environmental problem limits, or expands the responsible parties and affected populations. However, the commonalities among neoliberal environmental policies includes three distinct but complementary processes; privatization, commercialization, and commodification (Anderson and Leal 2001, Bailey 2007, Bakker 2005, Mansfield 2004).

Privatization is the process of changing ownership from public to private sectors (Bailey 2007, Bakker 2005). Concerning environmental policy to address commons issues, (environmental harm to any part of nature that is not clearly owned by any single party) is often turned to as a quick fix, as has happened with water rights, fishing rights, and now with global greenhouse gas emissions (Bailey, 2007, Bakker 2005, Mansfield 2004). Before proceeding, it is important to note the concept of the "tragedy of the commons" as it pertains to environmental pollution in general and climate change in particular.

The scenario posed by Hardin (1968) is one of a communal pasture for grazing sheep, if each shepherd acts in his own best interest, he will graze his sheep on the common land to increase his yield, adding still more sheep and continuing to overgraze the commons until they are destroyed. "Freedom in a commons brings ruin to all" (Garrett 1968: 1244). This particular notion was a neo-Malthusian remark about population, however it serves as a powerful notion in environmental research, particularly global climate change research. Like the shepherds, each nation is locked in a system in which increasing economic development almost certainly (without dramatic changes in behavior internationally, with full participation) means increasing greenhouse gas emissions, the costs of limiting the pollution are greater (at this point) than the costs the pollution generates for any one country. This understanding of the global commons is important when discussing the privatization of parts of nature considered common, and without single ownership. The move toward privatization is motivated by this notion of the tragedy of the commons, because if there are parties responsible to certain parts of nature, they are theoretically more inclined to conserve them.

The second process important in neoliberal policies on the environment is commercialization, or the actual introduction of commercial principles like efficiency, rational choice analyses (cost benefit equations), and profit maximization (Bailey 2007, Bakker 2005). Like its parent theory, market environmentalism, this aspect of neoliberal policy compels adherents to quantify the environment, both in terms of benefits for preservation, and costs for degradation. The third facet of neoliberal environmental policy is commodification, or the introduction of markets to standardize the environmental concern into a form which can dollar valued by market trading in a system of exchange (Bailey 2007, Bakker 2005).

Neoliberal environmental policy is not easily adopted and instituted by governments at any level, from local to international. It is important to temper any discussion of environmental policy and adoption, with an eye toward political engagement. Save those nations which are both totalitarian and environmentally concerned (a rare occurrence indeed), there are important stakeholders who need to buy in before large scale environmental policy is adopted. Three theories of political engagement when it comes to adopting environmental policy and law are public choice theory, capture theory, and the bootleggers and Baptists theory. Public choice theory sees the constant tension between competitive ideologies in any political decision, indeed, that the private interests of politicians are to advance their own agendas, but while bowing to the will of stakeholders, from lobbyists, industry, their constituency, and so forth (Bailey 2007, Dryzek 1997). Capture theory, instead views politicians truly wishing to serve the public interest, but with a lack of information and data to inform their policy decisions, they rely on industry, which manipulates the information and data to serve their interests, rather than the public interest (Bailey 2007, Ciocirlan and Yandle 2003). Finally, and perhaps most cleverly named, is the bootleggers and Baptists theory, which says that industry may openly claim to share environmental goals with politicians and the public, however their true concern, as always, is with their market share and competitiveness, in other words, the bottom line (Bailey 2007, Ciocirlan and Yandle 2003). Regardless of the avenue taken for political engagement, high levels of democracy are necessary for climate change mitigation policy to be broadly adopted.

Like most social theory, these theories of political engagement are not mutually exclusive, in fact, no one of them seems to fit well with the body politic of any one nation, or group of nations. Instead, the reality is some varied picture of politicians occupying the gambit from those absolutely co-opted by special interests, to those absolutely pure intentioned ideologues. It is important to include a discussion of political engagement with a topic as contentious as greenhouse gas emission reduction has proven to be. There are still those, although they are increasingly few, who adhere to the notion that global warming is not really an issue, and is instead a conspiracy of the weather channel to drum up ratings (Dickinson 2007). These theories seek to explain why some nations are faster to adopt neoliberal policies on the environment, especially for greenhouse gas emissions, than others.

Cap and trade policies represent a natural development in policy flowing from market environmentalism, and neoliberal ideas of environmental regulation, but which may operate to improve ecologically unequal exchanges and may certainly reduce greenhouse gas emissions. Cap and trade policies focus on the supply side of the commodified, cost benefit analysis of environmental harm, as opposed to alternative policies like taxes for pollution, which penalize the cost end (Bailey 2007, Montgomery 1972). Both industry and governments prefer cap and trade solutions for environmental problems because the terms are negotiated in agreement, and operate on a voluntary basis, making them seemingly easier to negotiate and pass into law. Negotiations can alter the timelines and minimum expectations for the polluters so that they may be reached in the most cost efficient manner (Bailey 2007). This is a preferred arrangement for industry, as straightforwardly imposed constraints may offer shorter timelines and cost industries more, threatening the everyday lives of individuals already unwilling to make sacrifices to mitigate climate change and its dramatic impacts on much of the world's population. Ideally, those living in affluent nations such as the United States would recognize their role in creating the climate crisis, but instead, the risk, like so many international social problems, is borne by peoples distant enough to be ignored within the wealthiest nations of the world. A cap and trade scheme allows those industries that are least efficiently able to change their emissions to buy additional time, while those who can reduce emissions in a shorter time frame get the market rewards for selling their allowances on the free market. This arrangement encourages an overall reduction by those industries who are positioned to begin reducing immediately, but have not recognized the benefits of doing so under the status quo.

A cap and trade program is a policy entered by a state, nation, region, or group of nations whereby members agree to institute a cap, or maximum level of emissions allowed, and to enter into a market exchange, where allowances (permits to emit a certain amount of a greenhouse gases) are traded, and whose prices are determined by the market (Metzger 2008a and 2008b). Other aspects of cap and trade programs may vary significantly across programs, for instance, the point of regulation, or in other words, the types of industries regulated by a cap and trade policy may be dramatically different across nations.

Policy and transparent governance are necessary to implement regulation which identifies which sectors or industries must participate in the cap and trade market, some nations focus on regulation upstream emitters, like oil refiners, and natural gas processors, and the allowances are used based upon when the products are consumed downstream (Metzger 2008a). Others focus regulation on downstream emitters, those who emit large quantities of a gas like coal driven power plants and large industrial manufacturers (Metzger 2008s). Still other cap and trade programs hybridize the targeted industry, including some upstream and some downstream sources of emissions (Metzger 2008a). Clearly the discussion of political engagement informs how any given nation makes these policy decisions. If the elected officials are compelled by the public's interest, and have access to reliable quality information, than the specific program will target first those industries which emit the most, if instead the politicians are motivated by political agenda or lobbyist pressure, or subjected to misleading information from industry, then the cap and trade program may not capture those sources of greatest concern.

Another important aspect of a cap and trade program that may vary widely across programs are offsets. Offsets represent a reduction in emissions that compensates for emissions elsewhere (Metzger 2008a). When these offsets are measurable, and certifiable, they become credits which are then traded on the market, and can be purchased by an emitter to offset their emissions. A complementary process to credits in cap and trade programs, are allowances. Allowances are the permits granted to emit a certain amount of a greenhouse gas. These allowances are distributed through an allocation process that may take several forms, again highlighting the importance of political engagement in designing the policy. The allocation of allowances has served as a major sticking point for many critics of cap and trade programs for greenhouse gas emissions (Lohman 2006, Parker 2008a and 2008b). The policy must outline how allowances will be allocated, whether they will be distributed freely at the outset, or only half to be given for free (as was the case with the European Union's Emissions Trading Scheme), or if all allowances were to be sold at market (Meitzger 2008a).

A final aspect of contention in cap and trade programs are their cost containment mechanisms. These are the rules and restrictions that limit the price of an emission to reduce market volatility and the concomitant effects such volatility could have on the economy as a whole (Meitzger 2008a). These are sometimes referred to as the safety valves for the emissions market. They may take many forms, from a group appointed to regulate the market, much like the securities and exchange commission regulates the stock exchange in the US, or they may simply take the form of a price limit, that prevents prices from rising beyond the limit, while still others may allow banking unused allowances for future years, or allowing offsets to be used to bring industries under their cap (Meitzger 2008a).

Cap and trade policies allow greater governmental certainty in guaranteeing emissions levels, and allow the unequal burdens of climate change policy to be spread across the sectors involved (Stavins 2008). This flexibility in implementation lets the greenhouse gas emitting entities decide for themselves where to make emissions cuts (Parker 2008a). Cap and trade programs also tend to be quite affordable, in fact the sulphur dioxide cap and trade system implemented by the US cost far less than was projected because of innovation (Parker and Yacobucci 2008).

The remarkable flexibility of cap and trade programs allow negotiations within a nation or region to determine the rules of the game, however, players are all motivated by self-interest, and policy makers are subject to imperfections, as the theories of political engagement suggest, so the importance of social scientists investigating all possible policy formations, and theories of these policy decisions, cannot be overstated (Liverman 1999 and 2004). Social scientists stand at a unique position, able to synthesize economic theory with policy development, implementation, and review.

Divestment as a strategy along with Cap and Trade policy allows for actionable movement toward mitigating climate change and its impacts. Perhaps more importantly, this two pronged approach places the impetus for change on those most able to afford to make substantive changes to the world to disrupt the business as usual approach to greenhouse gas emissions and promote real change in accordance with international consensus from the Intergovernmental Panel on Climate Change, and as agreed upon in the Paris Agreement.

Chapter 7: Conclusions

The coming global social problems of the 21st century have only begun to reveal themselves, but primary among them is, and will be, the impacts of climate change and its potential to transform whole societies either for better or for worse. This research has served to investigate the predictive power for the major bodies of sociological theory regarding greenhouse gas emissions. Of particular note is the inclusion of the halogenated species, to this point unanalyzed by sociologists concerned with climate change. Adaptation to climate change, and efforts to mitigate emissions stand to potentially address and mitigate the problems which attend international development. The current situation in which we find ourselves internationally is the result of the patterns of history with regard to economic development, colonization, and globalization. This march of history has proceeded upon the account of the natural environment, with little to no accounting for the costs to the natural world save when an ecosystem enters full collapse.

History provides examples of environmental stress as a social problem, in American history, the story of the "dirty thirties" colliding with the great depression serves as an example still within the lifetimes of some Americans as a touchstone that should serve as a lesson in the importance of avoiding human exemptionalism. The rain does not, in fact, follow the plow. Unfortunately, it is easy to disregard the effects of consumption in the wealthiest nations of the world, because so much of daily life seems divorced from the consequences of fossil fuel consumption. Despite their origins, finished consumer goods, and energy use, overuse, and waste all serve to further the consequences of climate change. Like environmental sociologists before me, I argue that the human exemptionalist paradigm defines much decision making, and must be abandoned in favor of a better recognition of the complex relationships between humanity and nature.

The study of the structural anthropogenic factors which propel greenhouse gas emissions, and therefore climate change and its impacts is interdisciplinary by nature of the complex interactions between the natural and social worlds. The theoretical frameworks which best characterize the relationships between structural level social factors and physical consequences in greenhouse gas emissions provides context for understanding, and implications for policy to mitigate emissions. In this research study, I employ four of the major bodies of social theory regarding greenhouse gas emissions, because like everything in the social world, reality is not captured in one monolithic lens, but instead social forces operated in varied ways requiring multiple perspectives to predict outcomes. To this end, structural human ecology, world-system theory, ecologically unequal exchange, and world polity theory interlock as perspectives where each brings an important concept and operationalization which helps explain variance in greenhouse gas emissions.

A key contribution of this research lies precisely in the breadth of outcomes analyzed. Although previous research into the structural variables which increase greenhouse gas emissions is informative, it is severely limited in scope, with the vast majority analyzing carbon dioxide, and to a far lesser extent methane gas emissions. I have instead included not just these and the remaining naturally occurring greenhouse gas, nitrous oxide, but I also analyze three greenhouse gases which are the product solely of human activity, with no naturally occurring sources. These gases, although seemingly linked to human activity and society, have yet to be analyzed by social scientists for assessing the role of society in impacting their emission levels. Although climate change mitigation will require adaptations and reductions across all of the greenhouse gases, the halogenated species result in greater impacts on the climate, and due to the human link also hold the potential to be dramatically reduced through the reordering of structures in society and the implementation of reduction policy and practice. Macro comparative sociology is in a particularly advantageous position for investigating the effects of the social order on the natural world, in particular the globalized problems of climate change, its inputs, and its impacts.

In this research, I drew from publically available datasets including the World Bank's World Development Indicators, Kick et al.'s block model for world-system position, and the Center for Systemic Peace's Polity IV Project (2015). For these data I chose the most recent year for which data were available, 2010. Important to understanding the differential impacts of society's structures on differing greenhouse gas emissions requires reasonably full coverage of data for the world's countries. Data availability has contributed to the monolithic presence of carbon dioxide in the social science literature investigating greenhouse gas emissions, my work benefits from the expanded data collection efforts on the part of the World Bank regarding greenhouse gas emissions. It is important to differentiate effects for each of the greenhouse gas emissions, as their sources differ, and the social structures which increase them also differ. Like using multiple theoretical perspectives as a mosaic to depict the most detailed picture of the social impacting the ecological, expanding my analysis to all of the major greenhouse gases better elaborates the relationship between society and nature.

Of my analyses, across all greenhouse gases, population and democracy stand apart as reliably affecting greenhouse gas emissions. Population served to influence each greenhouse gas emission, even when controlling for other variables. Democracy, on the other hand, was shown to decrease emissions for most of the greenhouse gases. Aside from the unifying social drivers affecting all greenhouse gas emissions, I also found differences between the classes of greenhouse gas emissions. The halogenated species of greenhouse gas emissions, the neglected greenhouse gases from the field of social sciences, emerged as affected by the age structure of the population, and average incomes per capita. As research on these greenhouse gases continues in the coming years, it will serve researchers well not to conflate all greenhouse gases with carbon dioxide.

The original contribution of this work, to expand structural understandings beyond carbon dioxide will stand to inform future research on the structural factors which increase or decrease greenhouse gas emissions. Climate change impacts will not and cannot be reduced without understanding the social structures which promote or discourage greenhouse gas emissions.

Together with enhanced levels of democracy, I propose two strategies to operate within the wealthiest countries to further mitigate climate change and its impacts. Focusing these strategies on the most affluent countries allows for these nations to help redress the consequences of the economic behaviors of the last century which have created the climate crisis. Divestment and a cap and trade market will allow nations like the United States to shift support away from high emissions industry, and emissions intensive manufacturing and transport. If contemporary history is our guide, it is through the economic bottom line that industry transforms its practices, not through the development of a corporate moral compass.

I return to my original research question as I close this research project, which theoretical perspective best predicts the societal mechanisms which drive greenhouse gas emissions? My conclusions show population is a persistent predictor for emissions, and that the world polity in general, and democracy in particular is key for reducing the environmental costs of development. I also find that global world-system position matters in determining the extent of ecologically unequal exchange when it comes to greenhouse gas emissions. Understanding the role of trade, and position within the globalized world-system can inform divestment strategies to support sustainable development and at the expense of traditionally extractive and exploitative trade relationships. Climate change may serve to be the defining social problem of a generation in the unfolding century, with the stakes for humanity high, promoting ecologically sound policy, strategy, and exchange between nations and within corporations is critical to mitigating the impacts of climate change and empowering the world's citizens with the resources to adapt to changes already evolving.

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Appendix A: Additional Tables

Table 20. World System Block Positions (Kick et al. 2011).

Block 1 Center Core Block	France, Germany, Italy, Netherlands, United Kingdom, United States
Block 2 Western European Block	Austria, Belgium, Brazil, Denmark, Finland, Greece, Ireland, Israel, Luxembourg, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey
Block 3 Asian Block	Australia, Canada, China, India, Indonesia, Japan, Korea, Rep., Malaysia, Pakistan, Philippines, South Africa, Thailand
Block 4 Eastern European Block	Albania, Bulgaria, Croatia, Czech Republic, Hungary, Malta, New Caledonia, Romania, Russian Federation, Slovak Republic, Slovenia
Block 5 Southeast Asian/Middle East Block	Afghanistan, Bahrain, Cameroon, Korea, Dem. Rep., Kuwait, Myanmar, Nepal, Oman, Saudi Arabia, Singapore, United Arab Emirates, Vietnam
Block 6 Former Soviet Block	Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Estonia, Georgia, Iceland, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Macedonia, FYR, Moldova, Turkmenistan, Ukraine, Uzbekistan,
Block 7 Middle East Block	Bangladesh, Cyprus, Egypt, Arab Rep., Iran, Islamic Rep., Jordan, Lebanon, Morocco, Sri Lanka, Syrian Arab Republic, Tunisia
Block 8 South American Block	Algeria, Argentina, Bahamas, Barbados, Bolivia, Cabo Verde, Chile, Colombia, Costa Rica, Cote d'Ivoire, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Kenya, Mexico, Nicaragua, Nigeria, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Venezuela
Block 9 African Block	Angola, Benin, Botswana, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Congo, Rep., Djibouti, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
Block 10 South Pacific Middle East Block	Bhutan, Brunei Darussalam, Eritrea, Fiji, Iraq, Lao PDR, Mongolia, Papua New Guinea, Qatar, Solomon Islands, Tajikistan, Tuvalu, Yemen

Table 21. Descriptive statistics for all continuous variables included in the analyses.

Variable	N	Mean	Standard Deviation	Skewness	Kurtosis
Carbon Dioxide (2010)	199	3.9939	1.09312	.095	-.630
Methane (2010)	134	4.1890	.66075	.228	.342
Nitrous Oxide (2010)	134	3.7493	.69851	.059	.194
Hydrofluorocarbon (2010)	88	2.8223	.99148	.019	.355
Perfluorinated Carbon (2010)	62	2.2272	.90518	-.069	-.020
Sulphur Hexafluoride (2010)	58	2.5561	.97821	-.492	.588
Total Population (2010)	214	6.5914	1.02762	-.399	-.405
Gross Domestic Product per capita (2010)	189	3.5602	.68324	.061	-.977
Quadratic Gross Domestic Product per capita (2010)	189	.4645	.46896	.943	.012
Non-dependent Population (2010)	195	63.4319	7.17647	-.130	-.069
Urban Population Percent (2010)	212	57.6314	24.39254	-.045	-1.069
Exports to High Income Countries (2010)	188	61.5794	21.49090	-.511	-.330
Exports to High Income Countries X Low Income Countries (2010)	207	18.5947	28.34864	1.163	-.168
Polity IV Index (2010)	163	3.8528	6.27776	-.773	-.825
International Non-Governmental Organizations (2010)	159	46.5157	17.65989	.520	.441

Table 22. Zero Order Correlations for Carbon Dioxide

Zero Order Correlations for Carbon Dioxide N=132																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Total Population (2010)																	
Gross Don	-0.076																
Quadratic	-0.056	0.031															
Non-depe	-0.053	.682**	-.226**														
Urban Por	-0.089	.794**	-0.106	.588**													
Exports to	0.093	.462**	0.107	.254**	.234**												
Exports to	0.159	-.710**	0.137	-.532**	-.647**	0.021											
WSP2	-0.032	.494**	.293**	.188*	.329**	.365**	-.293**										
WSP3	.455**	0.101	-0.081	0.162	0.049	0.043	-0.015	-0.117									
WSP5	-0.051	0.121	0.036	.254**	0.144	-0.162	-0.051	-0.1	-0.086								
WSP6	-.181*	-0.03	-.261**	.267**	-0.012	0.004	-0.084	-0.128	-0.109	-0.093							
WSP7	0.063	-0.009	-.187*	0.123	0.009	0.002	0.056	-0.1	-0.086	-0.073	-0.093						
WSP8	-0.011	-0.039	-.350**	-0.031	0.084	0.07	0.045	-.175*	-0.149	-0.128	-0.162	-0.128					
WSP9	-.187*	-.553**	.312**	-.677**	-.475**	-.226**	.375**	-.219*	-.186*	-0.159	-.203*	-0.159	-.278**				
WSP10	-0.138	-0.086	-0.014	0.019	-0.092	-.256**	-0.088	-0.094	-0.08	-0.069	-0.087	-0.069	-0.12	-0.15			
Polity IV I	0.04	.270**	0.138	-0.008	0.164	.285**	-0.106	.352**	0.157	-.377**	-0.092	-0.155	.208*	-.175*	-.196*		
Internatio	.324**	.502**	.262**	0.037	.415**	.417**	-.191*	.477**	0.117	-0.094	-.477**	0.074	0.029	-0.165	-.236**	.348**	
Carbon Di	.651**	.612**	-.200*	.577**	.488**	.309**	-.418**	.215*	.447**	0.083	0.005	0.078	-0.029	-.625**	-0.101	0.1	.437**
* p< 0.05, **p<.01																	

Table 23. Zero Order Correlations for Methane.

. Zero Order Correlations for Methane, N=109

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Total Population (2010)																	
Gross Don	-.220*																
Quadratic	-0.072	.360**															
Non-depe	-0.183	.586**	-0.003														
Urban Pop	-.237*	.788**	0.097	.487**													
Exports to	0.049	.481**	.200*	.220*	.255**												
Exports to	.264**	-.690**	-0.05	-.465**	-.637**	-0.032											
WSP2	-0.101	.497**	.407**	0.132	.303**	.394**	-.281**										
WSP3	.466**	0.042	-0.048	0.115	-0.019	0.019	0.032	-0.146									
WSP5	-0.104	0.077	0.084	.239*	0.105	-.218*	-0.016	-0.124	-0.106								
WSP6	-.267**	-0.122	-.257**	.236*	-0.099	-0.031	-0.043	-0.159	-0.135	-0.115							
WSP7	0.025	-0.077	-0.179	0.078	-0.055	-0.025	0.107	-0.124	-0.106	-0.09	-0.115						
WSP8	-0.049	-0.148	-.341**	-0.157	0.02	0.016	0.082	-.215*	-0.182	-0.155	-.199*	-0.155					
WSP9	-0.033	-.415**	0.108	-.577**	-.360**	-.207*	.290**	-0.166	-0.141	-0.12	-0.153	-0.12	-.207*				
WSP10	-0.109	-0.099	0.071	0.014	-0.035	-.242*	-0.083	-0.091	-0.077	-0.066	-0.084	-0.066	-0.113	-0.088			
Polity IV I	0.004	.282**	0.186	-0.104	0.153	.278**	-0.122	.357**	0.148	-.425**	-0.123	-0.185	.192*	-0.174	-0.153		
Internatio	.252**	.514**	.380**	-0.054	.385**	.432**	-.189*	.469**	0.087	-0.133	-.554**	0.046	-0.012	-0.088	-0.171	.341**	
CH4logge	.859**	-0.043	-0.038	0.055	-0.118	0.117	0.106	-0.073	.458**	-0.015	-.191*	-0.128	-0.073	-0.068	-0.063	-0.102	.229*
* p< 0.05, **p<.01																	

Table 24. Zero Order Correlations for Nitrous Oxide

Zero Order Correlations for Nitrous Oxide, N=109	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Total Population (2010)																		
Gross Domestic Produ	-.220*																	
Quadratic Gross Dome	-0.072	.360**																
Non-dependent Popu	-0.183	.586**	-0.003															
Urban Population Perc	-.237*	.788**	0.097	.487**														
Exports to High Incom	0.049	.481**	.200*	.220*	.255**													
Exports to High Incom	.264**	-.690**	-0.05	-.465**	-.637**	-0.032												
WSP2	-0.101	.497**	.407**	0.132	.303**	.394**	-.281**											
WSP3	.466**	0.042	-0.048	0.115	-0.019	0.019	0.032	-0.146										
WSP5	-0.104	0.077	0.084	.239*	0.105	-.218*	-0.016	-0.124	-0.106									
WSP6	-.267**	-0.122	-.257**	.236*	-0.099	-0.031	-0.043	-0.159	-0.135	-0.115								
WSP7	0.025	-0.077	-0.179	0.078	-0.055	-0.025	0.107	-0.124	-0.106	-0.09	-0.115							
WSP8	-0.049	-0.148	-.341**	-0.157	0.02	0.016	0.082	-.215*	-0.182	-0.155	-.199*	-0.155						
WSP9	-0.033	-.415**	0.108	-.577**	-.360**	-.207*	.290**	-0.166	-0.141	-0.12	-0.153	-0.12	-.207*					
WSP10	-0.109	-0.099	0.071	0.014	-0.035	-.242*	-0.083	-0.091	-0.077	-0.066	-0.084	-0.066	-0.113	-0.088				
Polity IV Index (2010)	0.004	.282**	0.186	-0.104	0.153	.278**	-0.122	.357**	0.148	-.425**	-0.123	-0.185	.192*	-0.174	-0.153			
International Non-Gov	.252**	.514**	.380**	-0.054	.385**	.432**	-.189*	.469**	0.087	-0.133	-.554**	0.046	-0.012	-0.088	-0.171	.341**		
Nitrous Oxide	.888**	-0.097	-0.023	-0.154	-0.112	0.132	0.166	0.02	.419**	-0.174	-.189*	-0.129	-0.041	-0.006	-0.162	0.108	.310**	
* p< 0.05, **p<.01																		

Table 25. Zero Order Correlations for Hydrofluorocarbons

. Zero Order Correlations for Hydrofluorocarbons, N=70

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Total Population (2010																	
Gross Domestic Produ	-0.141																
Quadratic Gross Dome	-0.048	.522**															
Non-dependent Popu	-0.118	.460**	0.008														
Urban Population Perc	-0.185	.802**	0.202	.411**													
Exports to High Incom	-0.007	.594**	.388**	0.23	.342**												
Exports to High Incom	0.174	-.704**	-0.089	-.515**	-.653**	-.320**											
WSP2	-0.119	.501**	.438**	0.139	.293*	.477**	-.285*										
WSP3	.436**	0.08	-0.004	0.16	0.033	-0.06	-0.062	-0.196									
WSP5	-0.152	0.177	0.051	.264*	.278*	-0.17	-0.129	-0.134	-0.088								
WSP6	-.322**	-.330**	-.351**	.307**	-.298*	-0.141	0.096	-.272*	-0.18	-0.123							
WSP7	-0.088	-0.064	-0.094	-0.038	-0.038	-0.129	0.057	-0.115	-0.076	-0.052	-0.106						
WSP8	0.069	-0.188	-.388**	-0.169	0.065	-0.076	0.078	-0.235	-0.155	-0.106	-0.216	-0.091					
WSP9	-0.025	-.436**	0.01	-.742**	-.373**	-0.187	.445**	-0.181	-0.12	-0.082	-0.167	-0.071	-0.144				
WSP10	-0.056	-0.232	0.099	-0.093	-.264*	-.348**	0.016	-0.066	-0.043	-0.03	-0.06	-0.025	-0.052	-0.04			
Polity IV Index (2010)	0.001	.419**	.332**	-0.004	.280*	.471**	-0.09	.388**	0.106	-.448**	-0.231	-0.119	0.063	-0.154	-0.149		
International Non-Gov	.279*	.637**	.515**	-0.021	.474**	.557**	-.256*	.499**	0.068	-0.118	-.659**	0.063	-0.007	-0.137	-0.183	.470**	
Hydrofluorocarbons	.547**	.590**	.300*	.415**	.410**	.416**	-.416**	0.218	.345**	0.008	-.238*	-0.062	-0.114	-.530**	-0.17	.272*	.493**
* p< 0.05, **p<.01																	

Table 26. Zero Order Correlations for Perfluorinated Carbons.

Zero Order Correlations for Perfluorinated Carbons, N=49																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Total Population (2010																	
Gross Domestic Produ	-0.362																
Quadratic Gross Dome	-0.324	0.645															
Non-dependent Popu	-0.194	0.393	-0.091														
Urban Population Perc	-0.315	0.802	0.336	0.423													
Exports to High Income	-0.119	0.444	0.342	-0.146	0.141												
Exports to High Income	0.357	-0.731	-0.217	-0.535	-0.664	-0.206											
WSP2	-0.293	0.445	0.392	-0.01	0.258	0.433	-0.294										
WSP3	0.456	-0.116	-0.16	0.067	-0.117	-0.156	0.112	-0.33									
WSP5	-0.301	-0.008	-0.052	0.33	0.165	-0.465	0.055	-0.235	-0.16								
WSP6	-0.306	-0.212	-0.408	0.151	-0.108	0.164	0.006	-0.26	-0.177	-0.126							
WSP7	0.154	-0.246	-0.228	0.015	-0.176	-0.233	0.172	-0.144	-0.098	-0.07	-0.077						
WSP8	0.216	-0.201	-0.235	-0.302	-0.011	-0.047	0.147	-0.178	-0.121	-0.086	-0.095	-0.053					
WSP9	0.007	-0.354	0.115	-0.42	-0.341	-0.039	0.371	-0.101	-0.068	-0.049	-0.054	-0.03	-0.037				
WSP10	-0.093	-0.341	0.083	-0.151	-0.379	-0.406	0.039	-0.101	-0.068	-0.049	-0.054	-0.03	-0.037	-0.021			
Polity IV Index (2010)	0.043	0.47	0.418	-0.314	0.251	0.564	-0.15	0.429	0.099	-0.596	-0.15	-0.351	0.04	-0.016	-0.2		
International Non-Gov	0.177	0.519	0.548	-0.187	0.292	0.44	-0.094	0.437	-0.055	-0.213	-0.559	0.014	-0.01	-0.177	-0.269	0.5	
Perfluorinated Carbon	0.649	-0.04	0.001	0.089	-0.038	-0.294	0.038	-0.19	0.43	0.033	-0.419	0.08	-0.205	0.002	0.037	-0.064	0.206
* p< 0.05, **p<.01																	

Table 27. Zero Order Correlations for Sulphur Hexafluoride.

Table 25. Zero Order Correlations for Sulphur hexafluoride, N=49																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Total Population (2010)																	
Gross Domestic Produ	-.576**																
Quadratic Gross Dome	-.409**	.827**															
Non-dependent Popu	-0.212	.304*	0.06														
Urban Population Perc	-.532**	.732**	.430**	.291*													
Exports to High Incom	-0.275	.389**	.439**	-0.195	0.012												
Exports to High Incom	.447**	-.704**	-0.279	-.373**	-.683**	-0.182											
WSP2	-.398**	.427**	.391**	-0.024	0.178	.437**	-0.269										
WSP3	.469**	-.341*	-0.2	-0.003	-.409**	-0.25	.337*	-.378**									
WSP5	-.293*	0.171	0.081	.509**	.335*	-.352*	-0.121	-0.198	-0.17								
WSP6	-0.202	-0.152	-0.188	0.076	-0.054	0.037	0.179	-0.137	-0.117	-0.062							
WSP7	0.123	-0.269	-0.212	0.018	-0.2	-.303*	0.169	-0.137	-0.117	-0.062	-0.043						
WSP8	0.123	-.290*	-.363*	-0.219	0.027	-0.076	0.03	-0.248	-0.213	-0.111	-0.077	-0.077					
WSP9	-0.163	-0.027	-0.127	-0.001	0.043	0.117	-0.059	-0.096	-0.082	-0.043	-0.03	-0.03	-0.054				
WSP10	-0.006	-0.19	-0.157	-.359*	-0.032	-0.055	-0.059	-0.096	-0.082	-0.043	-0.03	-0.03	-0.054	-0.021			
Polity IV Index (2010)	-0.02	.296*	.365**	-.381**	0.038	.410**	-0.025	.393**	0.068	-.646**	0.051	-.386**	0.029	-.319*	-0.074		
International Non-Gov	-0.049	.441**	.603**	-0.259	0.13	.502**	-0.141	.400**	-0.226	-.317*	-.413**	-0.025	-0.091	-0.039	-0.057	.402**	
Perfluorinated Carbon	.728**	-0.159	-0.093	0.143	-0.209	-.331*	0.12	-.323*	.435**	0.069	-.330*	0.149	-0.228	-0.033	-0.126	-0.271	-0.056
* p< 0.05, **p<.01																	

Table 28. Fully saturated models for the naturally occurring greenhouse gases with all independent variables.

	Carbon Dioxide		Methane		Nitrous Oxide	
	b	β	*b*	β	*b*	β
Urban Population	-0.001 (0.002)	-0.029	-0.004 (0.002)	-0.146	0.003 (0.002)	0.218
Non-Dependent Population	0.023*** (0.006)	0.174	0.023*** (0.007)	0.250	0.003 (0.007)	0.417
Population (logged)	1.000*** (0.054)	0.676	0.911*** (0.067)	0.925	0.988*** (0.073)	0.921
GDP per capita (logged)	0.742*** (0.106)	0.552	0.208 (0.132)	0.224	-0.002 (0.144)	-0.002
(GDP per capita (logged))^2	-0.194** (0.066)	-0.095	-0.045 (0.085)	-0.032	-0.029 (0.093)	-0.019
Exports to High Income Countries	-0.002 (0.002)	-0.037	0.0004 (0.002)	0.012	-0.0002 (0.002)	-0.006
Exports to High Income Countries X Low Income Countries	-0.001 (0.001)	-0.026	0.0003 (0.002)	0.001	0.0005 (0.002)	0.021
WSP 2	-0.020 (0.135)	-0.007	0.048 (0.143)	0.027	0.081 (0.157)	0.042
WSP 3	0.209 (0.153)	0.062	0.142 (0.161)	0.071	-0.054 (0.176)	-0.025
WSP 5	-0.010 (0.196)	-0.003	0.109 (0.221)	0.048	-0.178 (0.242)	-0.072
WSP 6	0.281 (0.211)	0.090	0.211 (0.240)	0.113	0.164 (0.263)	0.081
WSP 7	0.002 (0.188)	0.001	-0.259 (0.208)	-0.114	-0.358 (0.228)	-0.145
WSP 8	0.020 (0.174)	0.008	0.226 (0.193)	0.148	-0.015 (0.211)	-0.009
WSP 9	-0.061 (0.197)	-0.028	0.363 (0.219)	0.201	0.128 (0.240)	0.065
WSP 10	0.108 (0.215)	0.027	0.299 (0.245)	0.100	-0.138 (0.268)	-0.042
Polity IV	-0.010* (0.005)	-0.065	-0.013* (0.006)	-0.135	0.003 (0.007)	0.024
INGOs		0.045	0.003 (0.003)	0.096	0.003 (0.003)	0.072
Constant	-6.613*** (0.733)		-4.551*** (0.877)		-3.802*** (0.960)	
Mean VIF	5.122		4.987		4.987	
Highest VIF	14.352		11.869		11.869	
R^2	.937		.846		.844	
N	132		109		109	

Table 29. Fully saturated models for the halogenated species of greenhouse gases with all independent variables.

	Hydrofluoro-carbons		Perfluorinated Carbons		Sulphur Hexafluoride	
	b	β	*b*	β	*b*	β
Urban Population	0.004 (0.007)	0.071	-0.003 (0.010)	-0.064	-0.003 (0.007)	-0.066
Non-Dependent Population	-0.010 (0.020	-0.054	-0.012 (0.028)	-0.076	-0.012 (0.018)	-0.073
Population (logged)	1.141*** (0.152)	0.733	1.343*** (0.244)	1.902	1.197*** (0.168)	0.956
GDP per capita (logged)	0.915* (0.346)	0.564	0.212 (1.135)	0.145	0.940 (0.623)	0.661
(GDP per capita (logged))^2	0.270 (0.199)	0.126	0.452 (0.744)	0.245	0.050 (0.427)	0.029
Exports to High Income Countries	0.006 (0.005)	0.102	-0.013 (0.008)	-0.290	-0.007 (0.006)	-0.137
Exports to High Income Countries X Low Income Countries	-0.002 (0.005)	-0.038	-0.017 (0.015)	-0.402	0.001 (0.008)	0.021
WSP 2	-0.157 (0.268)	-0.063	0.462 (0.358)	0.243	0.051 (0.232)	0.030
WSP 3	-0.153 (0.302)	-0.046	0.638 (0.385)	0.277	0.163 (0.267)	0.088
WSP 5	-0.171 (0.499)	-0.038	1.734* (0.801)	0.588	-0.301 (0.695)	-0.104
WSP 6	0.112 (0.513)	0.043	1.250 (0.739)	0.459	-0.294 (0.529)	-0.073
WSP 7	0.239 (0.478)	0.046	0.768 (0.706)	0.170	-0.131 (0.563)	-0.033
WSP 8	-0.204 (0.413)	-0.071	-0.510 (0.526)	-0.137	-0.402 (0.341)	-0.166
WSP 9	-1.028 (0.564)	-0.295	1.558 (1.320)	0.247	0.024 (0.716)	0.004
WSP 10	-0.181 (0.787)	-0.021	1.363 (1.809)	0.216	-0.418 (0.608)	-0.074
Polity IV	0.002 (0.014)	0.015	0.014 (0.036)	0.095	-0.062* (0.030)	-0.461
INGOs	-0.012 (0.006)+	-0.233	0.010 (0.008)	0.238	-0.007 (0.006)	-0.146
Constant	-8.305** (2.489)		-7.918+ (0.287)		-7.735** (2.834)	
Mean VIF	5.429		11.649		7.963	
Highest VIF	15.824		78.865		42.688	
R^2	.851		.762		.860	
N	70		49		49	